The electric transmission of intelligence

Edwin James Houston

Eng

THE ELECTRIC
TRANSMISSION OF INTELLIGENCE.

AND OTHER

ADVANCED PRIMERS

OF ELECTRICITY.

BY

EDWIN J. HOUSTON, A. M.,

PROFESSOR OF NATURAL PHILOSOPHY AND PHYSICAL GEOGRAPHY IN THE CENTRAL HIGH SCHOOL OF PHILADELPHIA; PROFESSOR OF PHYSICS IN THE FRANKLIN INSTITUTE OF PENNSYLVANIA; ELECTRICIAN OF THE INTERNATIONAL ELECTRICAL EXHIBITION, ETC.

AUTHOR OF

"A DICTIONARY OF ELECTRICAL WORDS, TERMS AND PHRASES,"
"ELEMENTS OF PHYSICAL GEOGRAPHY," ETC.

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PREFACE.

In presenting the third volume of the "Advanced Primers of Electricity" the author wishes again to assert that these primers are in no sense to be regarded as revisions of his "Primers of Electricity" published during the International Electrical Exhibition held in Philadelphia, in 1884, under the auspices of the Franklin Institute of the State of Pennsylvania.

The International Electrical Exhibition Primers, written during the early days of the exhibition, were intended to explain merely the elementary principles of electricity to a public which was then almost entirely ignorant of even the rudiments of the science.

The times, however, have changed since 1884. The public is no longer ignorant of the principles of electrical science. The numerous commercial applications, which have been made since that time of this wonder-working force, have greatly increased the number of those to whom a knowledge of the laws of electricity has become a necessity of every-day business life.

Primers, therefore, based on the simple lines of those of 1884 would now occupy too limited a field, and the Author in rewriting his Primers has endeavored to treat the subject more nearly from the standpoint of the general public's knowledge.

The present volume of the "Advanced Primers," "The Electric Transmission of Intelligence and Other Advanced Primers of Electricity," treats in the main of the general principles of telegraphic and telephonic communication. This volume, like the others that have already appeared, is complete in itself, and can, therefore, be intelligently read independently of the others.

The Author has placed in this volume, as in the others, extracts from Standard Electrical books, for the purpose of giving the student some idea of their character and thus enabling him intelligently to select those best suited to his needs.

The Author desires to express his thanks to his friends Mr. Pedro Salom, Mr. Patrick B. Delaney, Mr. Clayton W. Pike and others for revision of some of the proof sheets.

EDWIN J. HOUSTON.

CENTRAL HIGH SCHOOL,

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I.—THE ELECTRIC TRANSMISSION OF INTELLIGENCE.

The very great velocity with which electricity can be propagated renders it especially adapted for the rapid transmission of intelligence between points situated at comparatively great distances from one another.

Various methods are employed for the transmission of intelligence by means of electricity. In all of these methods, however, the apparatus employed consists essentially of the following parts, namely:

(1.) A line wire or conductor, or its equivalent, connecting the points between which it is desired to establish communication.

(2.) Various transmitting instruments by means of which electrical impulses of the desired character are sent from one end of the line to the other end, or from any point in the line to some other point.

(3.) Various receiving instruments by means of which the impulses sent over the line are received and caused to produce signals of the desired character.

(4.) An electric source, or battery of electric sources, suitably connected with the line wire and designed to furnish the electricity required for the transmission of intelligence.

In some systems for the electric transmission of intelligence the sending and the receiving stations are situated at the ends of the line only. In most systems, however, various intermediate stations are employed, in which case any one of the stations can be placed in electrical communication with any of the remaining stations.

In all systems of electric communication both receiving and transmitting instruments are placed at each end of the line.

Where the lines are of very great length, in order to prevent the impulses which reach a very distant station from becoming too weak to properly produce or record the desired signals, it is customary to strengthen such impulses by means of local batteries that are automatically connected and disconnected with the line by different forms of instruments called relays.

Various systems of electric communication have been established which will be described in detail in subsequent portions of this book.

As regards the line wire or conductor it generally

consists of a metallic conductor in the shape of an iron or copper wire. This line wire or conductor is so placed in the circuit of an electric source and a transmitting instrument that electric impulses, the character of which will depend on the nature of the transmitting instrument, are sent into the line wire or conductor, and, passing through or influencing the receiving instruments connected with the line, produce in them various signals by means of which the desired intelligence is transmitted.

The line wire or conductor may be arranged either

(1.) In the form of what is called technically a metallic circuit, in which case a continuous metallic path is provided for the current not only as it flows out from the source through the transmitting instrument over the line to the receiving instrument, but also as it flows back again from the receiving instrument to the electric source. Such a circuit is called a metallic circuit, because all of its portions are formed of metallic conductors; or,

(2.) The line wire or conductor may form what is technically known as a ground-return circuit, in which metallic conductors or wires are provided for the passage of the electricity from the source through the transmitting instruments and over the metallic line to the receiving instruments only, the path

of the electricity back again to the source being formed by the earth or ground. This is, therefore, called a ground-return, because the ground acts as the return conductor.

In order to establish a ground circuit, or, as it is sometimes called, an earth-return circuit, the ends of the line wire at the transmitting and receiving stations are connected to comparatively large metallic plates that are buried sufficiently far below the earth's surface to reach permanently moist strata. Although the earth is in general a very poor conductor, yet, on account of its very great size, it readily acts as a return circuit of small resistance.

Great care is necessary, in establishing a ground return, to bury the plates in permanently moist earth. Wherever gas or water pipes are at hand, it is advisable to connect the earth wires to such pipes. If gas pipes are employed, the mains should be used in preference to the branch pipes, since the red lead employed in the joints of the branch pipes may produce considerable resistance, and in this manner prevent the ground from acting as an efficient return.

Metallic conductors, however, are not always employed for the line wire or conductor. In a curious form of instrument called the photophone, rays of

light have been successfully employed in place of line wires or conductors.

The line wire or conductor may consist of a bare metallic wire that is suitably supported on insulators placed on poles. Such lines or conducting wires are called aerial lines or wires. When they are employed it is of course requisite that their points of support should be thoroughly insulated.

In some cases it is necessary that the line wire or conductor should pass underneath a water surface or be buried in the ground. In such cases, since the surface of the line wire is brought into contact with comparatively good conductors throughout its entire length, it is necessary to entirely cover its surface with some insulating material; that is, it is necessary to employ what are called insulated wires. For ordinary purposes wires are insulated by being covered with a braiding or wrapping of cotton which is subsequently dipped into melted paraffine, or is provided with a coating of some suitable insulating material.

For subterranean or submarine purposes this insulated wire or conductor must be rendered impervious to moisture, and must, moreover, be further protected by a metallic armor or sheathing. Insulated conductors prepared in this manner for use under

ground, or under water, are known technically as cables. In most cases the cable contains more than a single line wire or conductor, although the word is sometimes applied to a single line wire or conductor so insulated and protected.

The line wire or circuit having been provided, in order to transmit intelligence between any two points in such circuit, the flow of electricity from the source through the circuit must be suitably modified by various forms of transmitting instruments.

In systems of ordinary telegraphic communication the transmitting instruments consist essentially of keys, the to-and-fro motions of which alternately open and close, or close and open, the circuit of the line wire or conductor. In some forms of keys not only is the circuit completed through the line wire or conductor, but the strength of the current permitted to pass through it is also varied, or the direction in which the current is flowing is varied, in order to produce certain effects in the receiving instruments. Keys of this character are employed in various systems of duplex and quadruplex telegraphy, where more than a single message is simultaneously transmitted over the same line wire or conductor.

In other forms of transmitting instruments the impulses sent into the line wire or conductor, in-

stead of being obtained by the movements of a key by the hand, are obtained in the movements of a diaphragm by sound waves. In such cases a current of a complex character, generally called an undulatory current, is sent over the line.

The receiving instruments employed in the various systems for the electrical transmission of intelligence are of a great variety of forms. Perhaps the commonest receiving instrument consists of some form of electro-magnet. As the impulses pass through the coils of the receiving electro-magnet, its armature is caused to move to-and-fro, and these to-and-fro motions are utilized for the production of various signals.

In the ordinary or Morse system of telegraphy these to-and-fro motions are caused to produce a succession of dots and dashes on a moving fillet of paper, by attaching to the armature of the electro-magnet a lever, one end of which is provided with a stylus or pencil. On the movement of the armature in one direction, the stylus or pencil is brought into contact with a moving fillet of paper, and on the movement of the armature in the opposite direction it is moved away from the fillet of paper. There will, therefore, be produced on the paper a dot or a dash, the length of which will depend on the time

the stylus or point is kept in contact with the paper. In the Morse system of telegraphy these dots and dashes are arbitrarily taken to represent the letters of the alphabet.

In the Morse sounder system the movements of the armature of the receiving electro-magnet are utilized to produce a series of clicks or sounds that are received by the operator as audible signals. In such cases there is no permanent record of the signals received.

In some systems of telegraphy the receiving electro-magnet takes the shape of a coil like that of a galvanometer, and variations in the current passing through it produce movements of a needle; movements in one direction corresponding to the dots, and movements in the opposite direction to the dashes of an alphabet similar to that of the Morse alphabet.

In a form of apparatus known as the printing telegraph, a series of impulses sent into the line wire or conductor are caused by suitable mechanism to record the message sent in regular printed characters.

In the telephone the undulatory impulses, or currents transmitted from one end of a line, are caused to produce articulate speech in suitably formed re-

ceiving instruments placed at some other part of the line.

In some cases the impulses sent over the line wire operate electro-magnets, the armatures of which are caused to ring bells or to release drops in a variety of apparatus known as annunciators, or to move a needle over an index, or to register the time when a distant contact has been opened or closed, or to do a great variety of similar work.

Or, the electric impulses may be caused, by the use of suitable receiving instruments, to move clock hands over the dial of a clock, to regulate a clock, or to set the hands of an ordinary clock at the correct time at regular intervals throughout the day.

Or, the electric impulses may be employed in various systems of railroad telegraphy for the purpose of setting signals, or for the purpose of giving any other information that may be desired.

Or, the electric impulses may be employed for registering the exact time of occurrence of a certain event up to a very small fraction of a second.

From the foregoing, which by no means include all the varieties of electric communication that may be readily established, it will be seen how extremely advantageous it is to employ an agency like electricity for the transmission of intelligence, the

velocity of which is not only so great as to render such transmission practically instantaneous, but whose effects can be varied at will in so many ways.

The various manners in which such intelligence can be so transmitted are given in detail, in the different sections of this book.

EXTRACTS FROM STANDARD WORKS.

Prescott, in his work on "Electricity and the Electric Telegraph,"* in referring to telegraphic or other electric currents, says on page 281 of Vol. I.:

"The line may, however, consist of two or more unequally conducting parts; for instance, it may be partly of copper and partly of iron, or of moist earth, water, etc. In this case the bad conductors weaken the current in every part of the entire circuit. When a telegraph line consists partly of iron wire and partly of moist earth or water, the weakening of the current caused by the bad conductors may be prevented if the sectional areas of these conductors are increased in the same proportion as their resistance.

"When Steinheil, in 1838, was making some experiments on the Nürnberg-Fürther railroad, for the purpose of determining whether the track could be used for telegraphic purposes, he noticed that the current passed from one of the rails to the other through the earth, and the thought occured to him whether it might not be possible to use the ground itself, and in this way dispense with half of the metallic circuit. This proved to be feasible, and he was then enabled thereafter to work his line with a single wire.

"The discovery by Steinheil that the earth may serve as a

* "Electricity and the Electric Telegraph," by Geo. B. Prescott. New York: D. Appleton & Co. 1892. 2 vols., 1221 pages, 722 illustrations. Price, $7.00.

conductor for the galvanic current is justly regarded as one of the most important discoveries in the art of electric telegraphy ever made, and it is one which has contributed very largely toward the extensive development of telegraphic lines. It is not easy to determine whether the earth really conveys the current in the manner of an ordinary conductor from one station to another, or whether it should be regarded merely as a reservoir into which the electricities of the battery pass. While reserving further remarks respecting the solution of the problem for future consideration, we wish for the present to accept Steinheil's opinion that the earth is a conductor and that the current actually passes through it from one station to another in order that what follows may be better understood."

II.—THE ELECTRIC TELEGRAPH.

A system of telegraphic communication, like any other system for the transmission of intelligence by electricity consists, as we have seen, of a line wire or conductor connecting two stations between which it is desired to transmit intelligence. Various transmitting and receiving instruments are generally placed not only at each end of the line, but also at intermediate stations between the ends.

The circuit so established is either metallic throughout—that is, a line wire or conductor is provided leading not only from the source to the receptive device, but also back again to the source—or employs the earth as a return. In this latter case the ends of the line wire are connected to metallic plates called ground plates that are buried sufficiently deep in the earth to reach permanently moist strata.

The earth, from its great mass, affords practically no resistance to the passage of a current, provided the wire or ground plate enters permanently moist

strata. This ability of the earth to thus act as a return wire or conductor was discovered by Steinheil.

A great number of telegraphic systems have been devised. In all, however, by means of various transmitting instruments, intermittent, rapidly varied, or pulsatory currents of electricity are sent into a line wire or conductor and produce certain signals in the receiving instruments. The receiving instruments, as a rule, consist of electro-magnets, the armatures of which, when non-polarized, are moved in one direction by the attraction of the magnetic poles produced in the electro-magnets by the currents circulating through their coils, and in the opposite direction by the movement of a weight or spring. When the armatures are polarized their movements, both from and toward the magnet poles, are produced by changes in the direction of the current.

A non-polarized armature consists of a mass of soft iron, suitably supported near the poles of an electro-magnet so as to be inductively magnetized and to be attracted toward it when the magnetizing current flows through the coils of the electro-magnet, and drawn away from it by the action of a spring or weight when such current ceases. Inasmuch as a soft

iron armature loses its magnetism as soon as the current ceases to pass through the coils of the electro-magnet, and is again rendered magnetic and attracted to such poles when such current begins to pass, it will move toward the magnet poles in no matter what direction the currents pass through the coils of the electro magnet.

A polarized armature, as its name indicates, consists essentially of a permanently magnetized armature, or of an armature which possesses a magnetic polarity independent of that which the electro-magnetic poles, between which it is placed, tend to produce in it. When a current is sent through the magnetizing coils of the electro-magnets, the magnet having the same polarity as the armature repels, while the magnet having the opposite polarity attracts, the armature, thus imparting to it almost double power. Reversal of current in the electro-magnet affects the armature in the opposite direction.

Receiving telegraph instruments may be, therefore, divided into two classes :

(1.) Those with non-polarized armatures, the movements of whose armatures follow changes in the strength of the current only.

(2.) Those with polarized armatures, the move-

ments of whose armatures follow changes in the direction of the current only.

The electric impulses sent over the line wire or conductor by the movements of the various transmitting instruments, pass through the magnetizing coils of the receiving instruments and produce either in the armatures of the magnets or in magnetic needles various movements that stand for certain arbitrary signs or characters representing the letters of the alphabet. In the Morse system of telegraphy the letters of the alphabet are represented by certain groupings of successive dots and dashes which are either recorded on fillets of paper or are caused to produce certain sounds, that are recognized by the operator at the receiving station. In the needle system of telegraphy the movements of magnetic needles, to the right or left of their vertical position when at rest, are employed in place of the dots and dashes of the Morse system arbitrarily to represent the letters of the alphabet. These movements are either read by the eye or are recorded on a moving fillet of paper.

There are two different ways in which the line wire or conductor may be connected to the circuit in a telegraph system, namely:

(1.) It may be maintained on closed circuit.

This system is generally employed in America in the Morse telegraph system.

(2.) It may be kept on open circuit. This method is employed in all needle systems, and in England in the Morse system.

In the Morse system of telegraphy, as almost universally employed throughout the United States, a series of makes-and-breaks are made to follow one another at pre-determined intervals, producing a succession

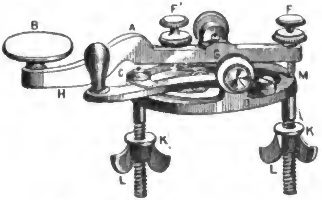

FIG. 1.—TELEGRAPHIC KEY.

of sounds of varying intervals or character, or a succession of dots and dashes which correspond to certain arbitrary characters representing the letters of the alphabet. In this system of telegraphy the circuit is opened and closed at the proper intervals by means of a telegraphic key, the general form and construction of which is shown in Fig. 1.

A metallic lever *A*, is pivoted at *G*, between two set screws *D D*, so as to have a slight up and down

movément, which is limited in one direction by a stop at *C*, called the anvil or front contact, and in the opposite direction by the set screw *F*, called the back stop. The front stop *C*, is provided with a platinum contact, which is brought into contact with, or separated from, a similar contact placed directly opposite it. These contacts are connected with the ends of the circuit, so that on the movement of the key by the operator, the line is closed or broken in accordance with the dots and dashes of the Morse alphabet. A spring, the tension of which is regulated by the screw *F''*, is provided for the upward movement of the key. When the key is not in use the line is closed by means of the switch at *H*.

In the United States the Morse system is operated on what is known as the closed-circuit system. In this system a battery is generally placed at both ends of the line.

Each station is provided with a key, relay, sounder, or register, and a local battery.

The closed-circuit connecting one station with another, being broken by the opening of the switch *H*, or the working of the key, the impulses so produced cause the armature of a relay to open or close the circuit of a local battery at the receiving station,

and thus operate a sounder or registering apparatus connected with said local circuit.

The Morse recorder is an instrument by which the to-and-fro movements of the armature of the receiving relay are reproduced locally and permanently recorded, so as to be readily interpreted by the operator at the receiving end of the line. In this instrument, as shown in Fig. 2, a paper fillet passes between a pair of rollers *r*, driven by the clockwork *W*. The upper roller is grooved, so that when the

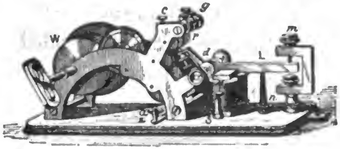

FIG. 2.—MORSE RECORDER.

stylus or point, at the bent end of the lever *L*, is pressed against the paper by the movement of the electro-magnet *M*, it may thereby indent or emboss the paper fillet. When no current is passing the lever *L*, is drawn back by the action of the adjustable spring at *n*.

In another form of recorder, called the ink-writing recorder, or register, and shown in Fig. 3, the record is made in ink on a fillet of paper that is drawn mechanically under the point of a stylus attached to

the armature of an electro-magnet and moved thereby. As in the recorder, the point or stylus is pressed against the paper whenever the armature is moved toward the electro-magnet, and is held there while the current is passing through the coils of the electro-magnet.

In the Bain recorder the dots and dashes of the Morse alphabet are marked on a fillet of paper that

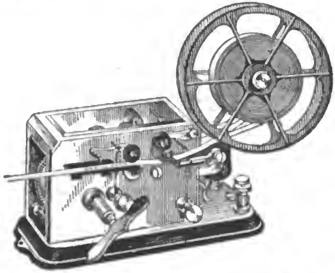

FIG. 3.—INK-WRITING RECORDER, OR REGISTER.

has been soaked in some chemical substance, like ferro-cyanide of potassium, that on the passage of the current, suffers decomposition, and so stains or marks the paper. The Bain recorder is shown in Fig. 4. The drum of brass *A*, is tinned on the outside. A paper fillet is drawn from the roll as shown, and kept pressed against the cylinder *A*, by a small wooden roller *B*.

The marking point or stylus is formed of iron, and is connected to the positive electrode of the battery, while the brass drum is connected to the negative electrode. As the iron point or stylus passes over the paper fillet, whenever the circuit is completed from the stylus through the fillet to the drum, the paper is marked with a blue dot or dash corresponding to the length of the time the current is passing.

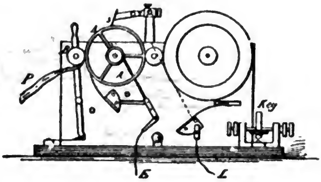

FIG. 4.—BAIN RECORDER.

In order to insure a moist condition of the paper fillet, a hygroscopic salt, that absorbs moisture from the air, like ammonium nitrate, is generally mixed with the ferro-cyanide of potassium.

In America, recording and registering apparatus are almost completely replaced by the Morse sounder. Operators under the old recording or registering system soon found that the dots and dashes of the Morse system could readily be interpreted by the

sounds they produce. This led to the invention of the Morse sounder.

A form of Morse sounder is shown in Fig. 5. The electro-magnet *M*, has its soft iron armature *A*, rigidly attached to the striking lever *B*, working in adjustable screw pivots, as shown. The other end of the lever is limited in its movements by two set screws *N*, *N*. The lower screw limits the approach of the armature *A*, to the poles of the magnet; the

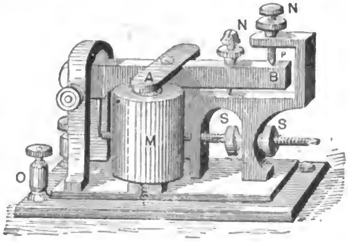

FIG 5.—MORSE SOUNDER

upper screw is set so as to give the lever *B*, sufficient play to produce a loud sound. A spring, provided with regulating screws *S*, *S*, is attached to the lever *B*, near its pivoted end, and pulls the lever back when the current ceases to pass through the electro-magnet *M*.

The dots and dashes of the Morse alphabet are reproduced by the sounder as audible signals that are

readily distinguished by the operator by the different sounds produced by the up and down stroke of the lever, as well as by the difference in the interval of time between successive signals.

Another form of telegraphic sounder, similar in its general construction to that already described, is shown in Fig. 6.

In long telegraph lines, especially when weak currents are employed, the electric impulses on reach-

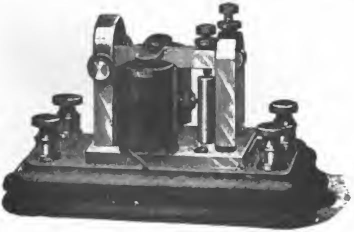

FIG. 6.—MORSE SOUNDER.

ing the distant end of the line are too feeble either to produce audible sounds in the sounder or to properly emboss the characters received on the paper fillets of the receiving apparatus. In such cases instruments called telegraphic relays are employed for the receiving instruments. All the work that the current is required to do is to operate delicately poised movable contact points, by means of which

the circuit of a local battery is opened or closed. In this circuit the sounder or recording instrument is placed.

A well-known form of relay is shown in Fig. 7. The electro-magnet is wound with many turns of fine wire. In the form used on the Western Union telegraph lines there are as many as 8,500 turns, having a total resistance of 150 ohms. The screw

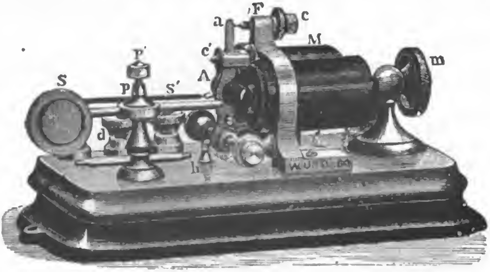

FIG. 7.—RELAY.

m, is provided for moving the electro-magnet *M*, from or toward its armature for the purpose of adjustment. A semi-cylindrical armature *A*, of soft iron, is attached to an armature lever *a*, the lower end of which is supported by a steel arbor pivoted between two set screws.

A retractile spring *S'*, regulable at *S*, is provided for moving the armature away from the electro-mag-

net. There are four binding posts, two of which are placed in the circuit of the electro-magnet, and two of that of the local battery. The ends of the line wire are connected with the former, and the local receiving instrument placed in the circuit of the latter. A platinum contact is placed on the end of a screw supported at *F*, opposite a similar contact, near the end *a*, of the armature lever.

On the passage of a current through the electro-magnet, the attraction of its armature closes the platinum contact points, and thus completes the circuit of the local battery, and causes an attraction of the armature of the local receiving apparatus. On the cessation of the current, the spring *S'*, pulls the armature away from the magnet, breaks the circuit of the local battery and thus permits a similar spring on the receiving instrument to pull its armature away. Thus all the movements of the armature of the relay are reproduced with increased intensity by the armature of the local receiving instrument.

The connection of the relay to the local battery and the registering apparatus will be better understood from an inspection of Fig. 8, which represents a form of relay much used in Germany. The retractile spring *f*, is regulated by the up-and-down movements of its lower support, which slides on its

vertical pillar *S*. The line wire is shown at *m*, *m*, connected at one end to earth by the ground wire.

The registering apparatus *R*, is connected in the circuit of the local battery *L*, as shown. The contacts are made by the end *B*, of the lever *B B'*, attached to the armature *A*, of the electro-magnet *M M*.

The arbitrary signs used in the Morse system representing the letters of the alphabet, numerals, punc-

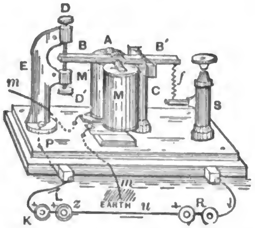

FIG. 8.—TELEGRAPHIC RELAY—GERMAN PATTERN.

tuation marks, etc., are registered in the recording instrument by means of various combinations of dots and dashes which follow one another at certain intervals. A dot is produced by the momentary contact of the transmitting key ; a dash is produced by a more prolonged contact. The intervals between the dots and dashes correspond to the time when no current is passing through the line. The arbitrary

characters representing the Morse alphabet are shown in the following table :

American Morse Code.

ALPHABET.

a · —	n — ·
b — · · ·	o · ·
c · · ·	p · · · · ·
d — · ·	q · · — ·
e ·	r · · ·
f · — ·	s · · ·
g — — ·	t —
h · · · ·	u · · —
i · ·	v · · · —
j — · — ·	w · — —
k — · —	x · — · ·
l ——	y · · · ·
m — —	z · · · ·

& · · · ·

NUMERALS.

1 · — — ·	6 · · · · · ·
2 · · — · ·	7 — — · ·
3 · · · — ·	8 — · · · ·
4 · · · · —	9 — · · —
5 — — —	0 ——

PUNCTUATION MARKS.

Period · · — — · ·	Interrogation — · · — ·
Comma · — · —	Exclamation — — — —

An ordinary dash is equal in length of time to three dots. The space between the separate characters of a single letter is equal to one dot, except in the American Morse in which the letters c, o, r, y, and z, contain spaces equal to two dots. L, is one and a half times the length of t, and cipher, zero, or naught twice the same length.

In needle telegraphy the receiving instrument operates by means of the movements of a needle over a dial. The needle is vertical when at rest. The alphabet of this system corresponds closely to the alphabet employed in the Morse system. The movements of the top of the needle to the right of the observer correspond to the dashes, and the movements to the left to the dots of the Morse alphabet.

	Printing	Single Needle		Printing	Single Needle
a	.—	\/	n	—.	/\
b	—...	/\\\	o	———	///
c	—.—.	/\/\	p	.——.	\//\
d	—..	/\\	q	——.—	//\/
e	.	\	r	.—.	\/\
f	..—.	\\/\	s	...	\\\
g	——.	//\	t	—	/
h	....	\\\\	u	..—	\\/
i	..	\\	v	...—	\\\/
j	.———	\///	w	.——	\//
k	—.—	/\/	x	—..—	/\\/
l	.—..	\/\\	y	—.——	/\//
m	——	//	z	——..	//\\

INTERNATIONAL TELEGRAPHIC CODE.

A difference, however, necessarily exists in the characters employed in the Continental Morse, from those employed in the American Morse telegraph, from the fact that spaces cannot be well represented by the use of the needle system. In European countries, therefore, where the Morse sys-

tem is used, and is recorded or printed as dots and dashes, those characters in which in the American Morse spaces exist will differ from those of the Continental characters. Most of the rest are the same.

This difference will be observed in the preceding table of the International Telegraphic Code.

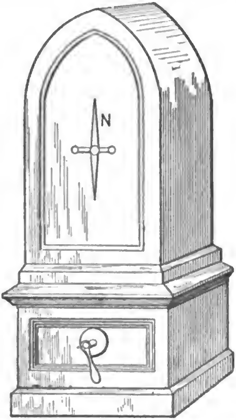

FIG. 9.—SINGLE-NEEDLE TELEGRAPHIC APPARATUS.

The single-needle telegraphic apparatus of Wheatstone and Cook is shown in Figs. 9 and 10, the former showing its external appearance and the latter its internal appearance as seen from the back.

An astatic needle is placed with one of its needles

inside two coils of insulated wire *C, C*; only one of these needles, *N*, is visible on the face of the receiving instrument. The current enters at *L*, passes through the coil *C, C*, and leaves the instrument at *N*.

In the system of needle telegraphy the movements of the needle to the right or left is obtained

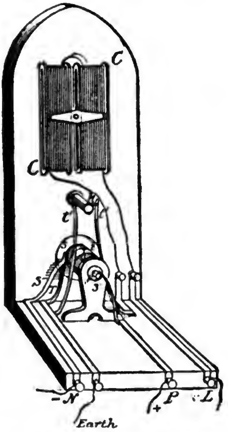

FIG. 10.—NEEDLE AND POINTER.

by changing the direction of the current in the coil *C, C*, Fig. 10. This is effected by working the handle shown in Fig. 9, which brings the contact springs into different positions on the commutator shown at *J*, in Fig. 9.

A more modern form of Wheatstone and Cook single needle apparatus is shown in Fig. 11. The arrangement of the needle in this latter instrument is shown in Fig. 12. A single needle *n s,* is placed inside the coil and has a long light needle *a b,* rigidly attached to it and used as a pointer only.

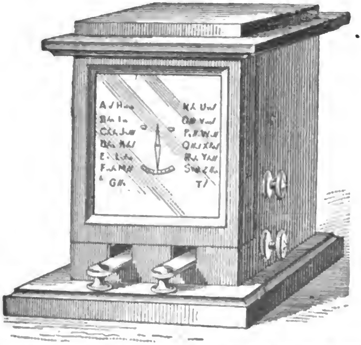

FIG. 11.—WHEATSTONE AND COOKE'S SINGLE-NEEDLE APPARATUS, EXTERNAL VIEW.

In step-by-step telegraphy, signals sent over a line wire or conductor are indicated by means of the movements of a needle over a dial on which the letters of the alphabet, numerals, etc., are marked. This system of telegraphy is sometimes called dial telegraphy, and is suitable for those who are unable to read Morse characters.

In Breguet's system of dial telegraphy a needle moves over a dial in one direction only by means of a step-by-step movement. The movements are obtained by the alternate to-and-fro movements of the armature of an electro-magnet, which imparts its motion, to a toothed wheel, shaped as shown in Fig. 13, by means of the action of the horizontal arm *c*, moving between the two prongs of a fork *d*, vibrat-

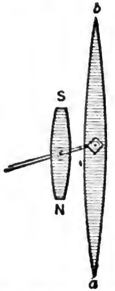

FIG. 12.—WHEATSTONE AND COOKE'S SINGLE-NEEDLE APPARATUS, INTERNAL ARRANGEMENT.

ing on a horizontal axis, to which a vertical plate is attached.

The receiving instrument is called the indicator, and consists, as shown in the Fig. 14, of a needle which moves over the face of a dial on which the letters of the alphabet and other characters are marked, as shown.

The sending instrument, called the manipulator, consists, as shown in Fig. 15, of a device for readily sending over a line the number of successive impulses that are required to move the needle from the last letter or character at which it stopped to the next letter or character which it is desired to transmit.

A dial on the face of which is marked the same characters as those on the dial of the indicator

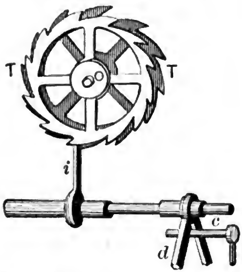

FIG. 13.—STEP-BY-STEP WHEEL.

is provided at its edge with a number of notches, in which a pin attached to a movable arm engages. This arm is so jointed that it can be placed in any of the notches on the face of the wheel.

Below the dial face, and attached to the same axis as the movable arm, is a wheel provided with undulations consisting of alternate elevations and depressions.

A lever *T*, placed at *a*, rests in these undulations at its upper end, and plays between two contact points at *P* and *Q*.

If, now, the dials of the indicator and the manipulator both being at zero, a movement is given to the arm by the handle *M*, at any point on the manipulator, there are thus produced the required number of makes-and-breaks to move the needle of the indicator to the corresponding letter or character.

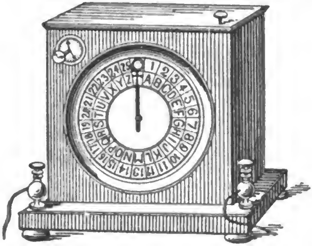

FIG. 14.—BREGUET'S INDICATOR.

Instead of employing step-by-step movements obtained by means of impulses sent over the line, for the movement of a needle over a dial, such movements may be utilized to operate a wheel on the circumference of which are placed ordinary printing types. By these means the message is recorded on a fillet of paper in printed characters. Such a system

of telegraphy is called the printing telegraph. Fig. 16 represents Callahan's printing telegraph or stock ticker.

The telegraphic stock ticker consists of means whereby stock quotations are automatically sent over a line to any desired number of subscribers and recorded in printed characters. A double type-wheel, maintained in motion by any suitable means, is so

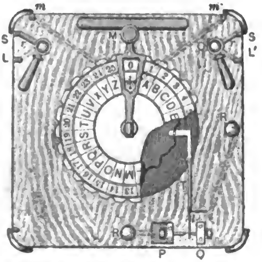

FIG. 15.—BREGUET'S MANIPULATOR.

placed as regards a paper fillet that the different types fixed on its circumference imprint letters on the paper fillet whenever it is brought into contact therewith.

When the desired letters come opposite the paper fillet, the type wheel is stopped by the motion of a polarized relay working between the poles of an electro-magnet furnished with a soft iron or non-po-

larized armature. The movements of the armature of the printing magnet release a train and thus insure the impression on the paper fillet of the characters which it is desired to print.

The type-wheel is driven by a step-by-step movement obtained by rapidly alternating pulsations. Although these electric pulsations pass through the coils of the printing magnet, yet they follow one

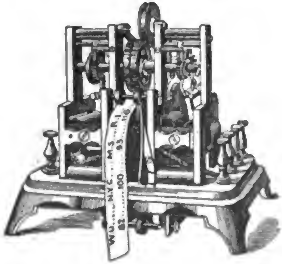

FIG. 16.—CALLAHAN'S PRINTING TELEGRAPH.

another too rapidly to affect its armature until a pause is made, when the armature is attracted and the printing mechanism released.

In the system of automatic telegraphy the speed of transmitting a message is greatly increased by the use of a previously prepared fillet of paper containing the perforations in the shape and order required to form the message to be transmitted.

In the earliest system of automatic telegraphy, that of Bain, the paper passes between the terminals of the main line and the battery, the circuit being completed when the terminals come in contact at the perforated parts, and broken when separated by the unperforated parts of the paper. In this system of telegraphy some form of registering or recording apparatus is employed, since the separate characters would follow one another too rapidly to be read by sound. A number of other systems are in use.

In the Wheatstone system three parallel lines of perforations are made in a paper fillet. The perforations of the central line, which are used only for drawing the paper through the transmitter by the projections of a revolving spur-wheel catching in the holes, are at equal distances apart. The holes on the top and bottom lines, which permit pins on an oscillating lever to make contact alternately with the positive and the negative pole of the battery, are at varying distances so as to produce the arbitrary characters required for the alphabet. The holes for a dot effect a reversal at each oscillation; those for a dash, at every other oscillation.

The automatic system of telegraphy is sometimes called machine telegraphy.

In the system of fac-simile telegraphy, a copy of a chart, diagram, picture, or signature is telegraphically transmitted from one station, and reproduced at a distant station. This system of telegraphy is sometimes called autographic telegraphy or pan-telegraphy.

A system of fac-simile telegraphy invented by Bakewell is shown in Fig. 17. Two similar metallic cylinders *c, c*, placed at the ends *M* and *M'*, of a telegraph line *L*, and maintained in synchronous rota-

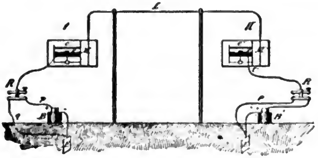

FIG. 17.—BAKEWELL'S FAC-SIMILE TELEGRAPHY.

tion, are provided with metallic arms or tracers *r* and *r'*, placed on a horizontal screw connected to a line circuit, and moved laterally over its surface during its rotation.

The chart, writing or other design, to be transmitted, is traced with varnish or other non-conducting substance on the surface of the metallic cylinder at the transmitting station and a sheet of chemically prepared paper, similar to that employed in the Bain

recorder, is placed on the surface of a cylinder at the receiving station *M'*.

The two cylinders being synchronously rotated, as the metallic tracer at the transmitting end, when it moves over the non-conducting lines on the cylinder breaks the circuit in which it is placed, and causes corresponding breaks in the otherwise continuous blue spiral line traced on the paper-covered surface at *M'*.

Telegraphic keys at *R* and *R'*, are used for the purposes of ordinary telegraphic communication before or after the record is transmitted.

A curious system of telegraphy, named induction telegraphy, has been devised, whereby communication can be established between moving trains or cars and fixed stations along a railroad by means of impulses transmitted by induction between the moving train and a wire parallel to the track.

Two systems of induction telegraphy have been proposed, namely :

(1.) The Electrostatic Induction System.

(2.) The Current Induction System.

In the electrostatic system, one condensing surface consists of a wire placed along the road so as to come as near to the top of the cars of the moving train as possible. The other condensing surface is

formed of the metal roofs of the moving cars. Each condensing surface is connected to suitable instruments and batteries and to earth. The line wire at the fixed station is connected to the earth through a ground plate, and the metal roof of the car to earth through the wheels and track. Under these circumstances variations in the charge of either of the condensing surfaces produce inductive impulses that are received by the other surface; telegraphic signals are sent and received in Morse characters, but, instead of the ordinary telegraphic receiver being employed, a telephone is used.

In the current induction system the fixed wire is placed in a circuit near the track, so as to be parallel with a coil of insulated wire placed on the car which receives the inductive impulses. The coil of wire on the train is connected with instruments and batteries as a metallic circuit. The line wire is also connected with batteries and receiving and transmitting instruments.

In the current induction system, as invented by Phelps, the fixed line consists of a No. 12 copper wire placed inside a wooden strip laid on the roadbed between the tracks.

A coil composed of some 90 turns of No. 14 copper wire passes through a tube suspended longitudi-

nally under the car, the upper parts of the coil passing through the car and being hung up along the sides over the windows.

Receiving instruments, consisting either of Morse sounders or of telephones, are connected in the circuit of the moving coil. The transmitting key, instead of merely making and breaking a battery circuit, throws a buzzer into or out of action, whereby a musical sound is produced in the telephone as long as the circuit is kept closed.

A difficulty experienced in actual practice in the case of any induction system is where more than a single line wire or conductor is employed on account of the confusion arising from the mutual induction of the lines on one another, thus causing "cross talk."

Perhaps one of the most curious illustrations of induction telegraphy is seen in some recent experiments of Mr. Preece, of London, who, according to *The Spectator*, has put up a mile of wire on the coast of the Bristol Channel, near Lavernock, and a shorter wire on Flatholm, an island some three miles distant in the channel. The island was used as the receiving station, its wire circuit being fitted up with a sounder to receive messages. The circult on the mainland was connected to a powerful telephonic

generator, and when a message was sent through this circuit it was distinctly received on the island. Here the message was presumably sent by induction through the air, or, more strictly speaking, through the intervening ether.

EXTRACTS FROM STANDARD WORKS.

In a volume by Reid, called "The Telegraph in America and Morse Memorial," * on page 62, the following description is given by Morse of his inventions of the electro-magnetic telegraph :

"Still, between the years 1800 and 1832, the means by which that end was to be accomplished were all *semaphoric. Decomposition* by dynamic electricity in the form of *gas-bubbles*, and the *deflection* of the *magnetic needle*, were the sole novelties in the signals of their proposed plans. No period, therefore, is more strongly isolated from all previous dates than the date 1832 as the epoch of a *new method* of applying electricity by the *electro-magnet* to the *creation of a* NEW ART, of a *new method* of communicating to a distance, to wit, *recording*, a method wholly unlike any previously imagined or invented.

"But the instrument I had devised in 1832, and constructed in 1835 (so far, at least, as to demonstrate its practicability to communicate *from* one station *to* a distant station) did not completely embody my *whole plan*. This *whole plan* was not complete until I could, by a *duplicate* of the instrument, have the means of a return from that distant station. This was necessary in order to *receive from*, as well as to

*"The Telegraph in America and the Morse Memorial," by James D. Reid. New York: The W. J. Johnston Co., Ltd. 1879. 894 pages, 75 steel engravings. Russia binding. Price, $7.

send to, a particular station. The *whole plan* comprised intercommunication or reciprocal communication.

"Between the date, 1835, of the completion of the first instrument, and 1837, the date of its more public exhibition, there was a very important addition to it, which I had already devised, and provided against a foreshadowed exigency, to meet it if it should occur, when the conductors were extended, not to a few hundred feet in length in a room, but to stations many miles distant. I was not ignorant of the possibility that the electro-magnet might be so enfeebled, when charged from a great distance, as to be inoperative for *direct* printing. This possibility was a subject of much thought and anxiety long previous to the year 1836, long previous to my acquaintance or consultations with my friend Prof. Gale on the subject; but I had then already conceived and drawn a plan for obviating it. The plan, however, was so simple that it scarcely needed a drawing to illustrate it; a few words sufficed to make it comprehended. If the magnet, say, at twenty miles distant, became so enfeebled as to be unable to print *directly*, it yet might have power sufficient to close and open another circuit of twenty miles further, and so on until it reached the required station. This plan was often spoken of to friends previous to the year 1836, but early in January, 1836, after showing the original instrument in operation to my friend and colleague Prof. Gale, I imparted to him this plan of relay battery and magnet to resolve his doubts regarding the practicability of my producing magnetic power sufficient to write at a distance."

III.—MULTIPLE TELEGRAPHY.

Various devices have been invented for the purpose of increasing the capacity of a single telegraph line so as to permit more than a single message to be simultaneously sent over it.

Any system of telegraphy by means of which this can be accomplished is called a system of multiple telegraphy. The term multiple telegraphy is by some limited to the simultaneous transmission of more than four separate despatches.

The following are the most important systems of multiple telegraphy, namely:

(1.) Duplex Telegraphy.

(2.) Quadruplex Telegraphy.

(3.) Synchronous-Multiplex Telegraphy.

(4.) Harmonic Telegraphy.

(5.) Phonoplex Telegraphy.

In 1852 Moses G. Farmer, of America, first suggested the idea of simultaneously sending two dispatches over a single wire. Gintil, however, of Austria, was the first to produce a system by means of which double transmission was actually accomplished.

Duplex telegraphy is the name applied to a system of telegraphic communication by means of which two messages can be simultaneously sent over a single line wire or conductor.

Duplex telegraphy may be conveniently divided into diplex telegraphy, in which two messages are simultaneously sent over the line wire in the same direction, and contraplex telegraphy, in which they are sent over the line in opposite directions.

In general use, however, the term duplex is limited to a simultaneous transmission of two messages in opposite directions.

There are two varieties of duplex telegraphy in use, namely:

(1.) The bridge method.

(2.) The differential method.

In any system of duplex telegraphy two conditions must be obtained, namely:

(1.) The receiving relay at one end of the line must not respond to the key at that end.

(2.) The currents coming from either end of the line must be provided with a free and uninterrupted path to the earth or ground.

In the bridge method of duplex telegraphy the receiving relay *M*, Fig. 18, is placed in the cross wire of a Wheatstone bridge, the four arms of which

are formed as follows: The two left-hand arms, as shown at the left of the figure, are formed by adjustable resistances *A* and *B*. The two right-hand arms are formed respectively by the line wire and the adjustable resistance *R*, connected to the condenser *C*, as shown.

The transmitting key at *K*, has one of its terminals connected to the point *H*, of the bridge, and the other to the free terminal of a battery, whose re-

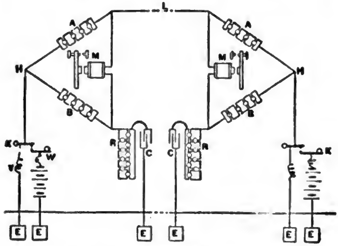

FIG. 18.—BRIDGE METHOD.

maining terminal is grounded at *E*. Small resistances are inserted at *W* and *V*, in the circuit of the battery, to prevent injurious short-circuiting.

A similar disposition of apparatus is placed at the other end of the line. If, now, the four resistances at one end of the line are suitably adjusted, the relay at that end will not respond to the outgoing current, but, since an earth circuit is employed, it will

respond to an incoming current. The relay at either end, therefore, will respond only to signals from the other end of the line. Consequently the operator may signal a distant station, while at the same time the relay at his own end of the line, not being affected by his sending, is in readiness to receive signals from the other end.

In the differential method of duplex telegraphy, the receiving relays are wound differentially, that is, two magnetizing coils are wound on the core of the receiving electro-magnet in opposite directions, so that if the currents passing through both coils of a relay of one station are of the same strength, no magnetic effects will be produced in the core. The deflecting action of the relay will, therefore, be nothing. If, however, the current of one of the coils in this relay is strengthened by the current from the distant station, it overbalances the current in the other coil, and this gives the signal.

In this way, therefore, the conditions necessary for duplex telegraphy are fulfilled. Namely, the relay at either end does not respond to the key at that end, but does respond to the key at the other end of the line.

The arrangements of the apparatus required for the differential method of duplex telegraphy are

shown in Fig. 19. The coils at the receiving or transmitting relays or galvanometers at *A* and *B* are differentially wound. One of the coils *A*, is connected to that of *B*, through the line as shown, and the other in each to the rheostats at *R* and *R'*.

The battery at *A*, has its copper terminal, and that at *B*, its zinc terminal, connected to the earth. When the keys at *A* and *B*, are simultaneously depressed the currents flow into the line in the same direction and strengthen each other.

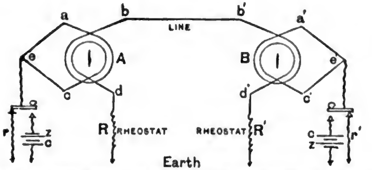

FIG. 19.—DIFFERENTIAL METHOD OF DUPLEX TELEGRAPHY.

The two currents in duplex telegraphy do not, therefore, pass each other on the line; on the contrary, they are sent into the line in the same direction.

Since, when either key is moving, there is a small interval of time during which the circuit is broken by incoming currents, the keys are generally made to close the second contact before breaking the first.

Quadruplex telegraphy consists of methods by

means of which the simultaneous transmission of four messages is obtained over a single line wire or conductor; two in one direction, and the remaining two in the opposite direction. Quadruplex telegraphy consists in means whereby duplex telegraphy is duplexed. There are therefore two methods of quadruplex telegraphy; namely, the bridge method and the differential method.

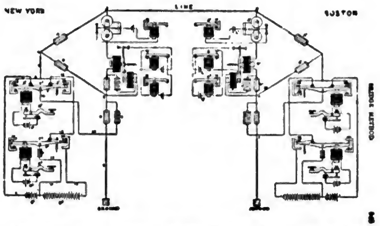

FIG. 20.—QUADRUPLEX TELEGRAPHY, BRIDGE METHOD.

In the bridge method of quadruplex telegraphy, changes both in the polarity and strength of the current are utilized to establish a double duplex system of transmission.

The general arrangement of apparatus employed in the bridge method of quadruplex telegraphy is shown in Fig. 20.

Two receiving relays *R′* and *R″*, are placed at each end of the line.

R', is a polarized relay, the movements of whose armature in opposite directions are obtained by means of changes in the magnetic polarity of its magnet. This relay, therefore, responds to changes in the direction in which the current flows through its magnetizing coils, but not to changes in the strength of such current.

The other relay *R''*, which is non-polarized, responds to changes in the current strength, but not to changes in the direction of the current passing through its magnetizing coils. These relays, *R'* and *R''*, are placed in the bridge wire of a Wheatstone bridge, formed in general after the manner of the bridge in duplex telegraphy.

The entire apparatus, consisting of transmitting keys, relays, etc., is duplicated at the other end of the line. Under these conditions, as in the case of duplex bridge telegraphy, the signals transmitted from either end of the line affect the instrument at the other end of the line only, but not their own instrument.

The changes in the direction of the current required to produce changes in the polarity of the relay *R'*, are obtained by the means of the double current transmitter, or pole changer, shown at *T''*, with its operating key *K'*, and local battery *e'*. This instru-

ment interchanges the poles of the main battery *E'*, when *K'*, is depressed, and thus reverses the polarity of the current on the line. The changes required in the strength of the current passing through the relay *R''*, are obtained by means of the increment transmitter T^2, which is connected to the battery wire 12 of *T'*, in such a way that when *K'*, is depressed the main battery *E'*, is placed in series with the battery *E*, of say twice the strength of *E'*, thus

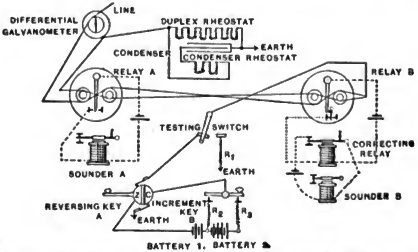

FIG. 21.—DIFFERENTIAL METHOD OF QUADRUPLEX TELEGRAPHY.

permitting a current of threefold the original strength to be sent into the line.

The general arrangement of apparatus required at one end of the line in the differential method of quadruplex telegraphy is shown in Fig. 21. Exactly similar apparatus is placed at the other end of the line. In this system there are two differentially wound relays at each end of the line. One of

these, at *A*, gives signals on changes in the direction of the current, but none on changes in the strength of the current. The other, at *B*, gives signals on changes in strength of the current, but none on changes in its direction. The two relays are therefore independent of each other, and operate sounders that are under the independent control of two distinct receiving operators. For the general details of the apparatus in differential quadruplex telegraphy the reader is referred to some more advanced work on the subject.

In synchronous multiplex telegraphy, a number of messages, amounting in some cases to as many as 72, can be simultaneously sent over a single line wire or conductor, either all in the same direction, or part in one direction and the remainder in the opposite direction.

The system of synchronous multiplex telegraphy invented by Delany, of America, embraces the following parts:

(1.) A circular table of alternately insulated and grounded contacts, placed at each end of a telegraph line wire or conductor.

(2.) A synchronized rotating arm or trailing contact at each end of the line, driven by a phonic wheel, and maintained in rigorously synchronized

rotation by means of electric impulses automatically sent over the main line in either direction on the failure of either wheel to rotate synchronously with the other wheel.

(3.) Transmitting and receiving instruments connecting similar contacts at each end of the main line, and forming practically separate and independent lines for the simultaneous transmission of dispatches over the main line in either direction.

The main line, which is simultaneously connected at both of its ends to corresponding operating instruments, is transferred so rapidly from one set of instruments to another that the operators, either sending or receiving, do not realize the fact that the line has been disconnected from their instruments and given to others, because each will always have the line ready for use, and, to all practical intents and purposes, each operator will therefore have at his disposal a private wire between himself and the operator with whom he is in communication.

Although more than one operator may be regarded as simultaneously using the line at any given time, yet, in point of fact, no two operators are in reality using it absolutely at the same time; they merely follow one another at so short intervals, and the line is taken from one and transferred to anoth-

er so rapidly, that no one can tell but that he alone has the line, and that, therefore, it is practically open for the use of every operator just as if he alone had control of it.

There will thus be established, by the use of a single line, as many private and separate lines as there are transferences of the line from the time it is taken from the first operator and again given back to him.

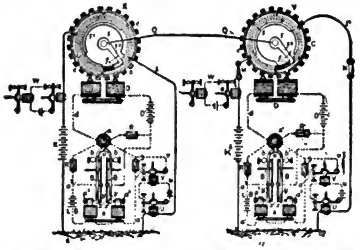

FIG. 22.—DELANY'S SYNCHRONOUS MULTIPLEX TELEGRAPH.

The synchronous multiplex system has been extended to as many as seventy-two distinct and separate printing circuits, maintained and operated on a single connecting line wire.

The speed at which the circuits may be operated is in the inverse order of the number of circuits organized. Practically, the best results are obtained from six divisions of the contacts in the circle, and the use

of the Morse system. Each operator gets about thirty-six contacts with the line per second, a rate which admits of the highest speed of transmission on each of the six circuits.

The arrangement of the apparatus at each end of the line is shown in Fig. 22.

The circular tables with their insulated contacts and trailing arms are shown at each end of the line at *Z* and *Y*. These arms are maintained in synchronous rotation by means of the electro-magnets at *D*, *D*, which are energized by rapidly intermittent currents, obtained by means of the vibrating forks at *B B*, and *B B*.

Devices are provided for maintaining each arm in synchronous rotation with the other by means of electric impulses sent over the line when one arm tends to get out of synchronism with the other.

The details of the working and receiving circuits at each end of the line are shown at Fig. 23.

In Gray's harmonic multiple telegraphy, means are provided for the simultaneous transmission of a number of separate and distinct musical sounds over a single wire. The separate tones are utilized for the transmission of an equal number of telegraphic messages.

Electric impulses corresponding to the separate

tones are thrown into the line wire by means of tuning forks maintained in vibration by electro-magnets. These forks interrupt the circuit of batteries connected with the main line at the sending end. A number of such forks vibrating at different rates and producing different musical tones

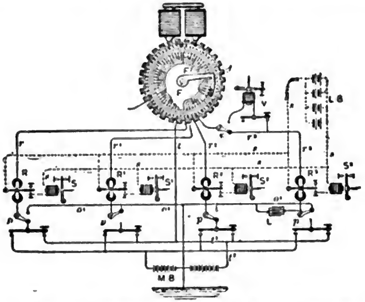

FIG. 23.—WORKING AND RECEIVING CURRENTS.

are so connected with the main line as to simultaneously send into it electrical impulses at different rates.

The composite tones thus impressed on the main line are separated into their component tones at the receiving end by electro-magnets called harmonic receivers. The armature of each receiver consists of a steel ribbon or plate tuned to exact unison with one of the tuning forks at the sending end. As the

complex or undulatory currents pass through the coils of each harmonic receiver, that note, and that note only, affects the particular armature that is in unison with its ribbon or reed. The operator, therefore, at this receiver is in communication only with the operator at the key of the circuit that is sending this particular note into the line. The Morse alphabet is used, the dots and dashes being received as musical tones of different durations. By an ingenious device these signals are sometimes converted into recorded Morse characters.

In phonoplex telegraphy, pulsatory currents actuate a modified telephonic receiver which permits the simultaneous operation of the regular Morse and a superposed phone circuit also operated by the Morse system.

The simultaneous Morse transmission of telegraphic and telephonic messages over a single wire has also been accomplished by causing, by means of instruments called graduators, the makes and breaks to take place so gradually that they fail to appreciably influence the diaphragm of the telephone. This system is objectionable on account of increased reresistance and electro-static capacity.

EXTRACTS FROM STANDARD WORKS.

In their work called "The Quadruplex" * Maver and Davis, speaking of the effect produced by opposing similar poles of a battery to each other at different ends of a telegraph line, say on page 38 :

"There is probably nothing in the operation of the polar duplex or quadruplex more difficult of comprehension to the beginner than the effect produced by the placing of similar poles of batteries against each other. For instance, if we take a battery of 100 cells at one end of the line and of 50 cells at the other end, and place the positive poles of each battery to the line, there will be, roughly speaking, a strength on the line equal to that from a single battery of 50 cells, and the beginner is generally at a loss to understand what becomes of the strength of the remaining 100 cells. To tell him that 50 cells at one end are neutralized at the other end is not always satisfactory.

"Perhaps the following homely illustration will make it somewhat plainer :

"Let us imagine a railway train with a locomotive at each end of the train, each locomotive to have a strength of 50. If we oppose the strength of these engines against each other, we know that the train will not move. Now, if we bring another locomotive having also a strength of 50 and

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* "The Quadruplex." By Wm. Maver, Jr., and Minor M. Davis. New York : The W. J. Johnston Company, Ltd. 1893. 128 pages, 63 illustrations. Price, $1.50.

place it at one of the ends, the train will now move, but urged only by a strength in all of 50, although there is a locomotive force of 150 being exerted on the train. In other words, the power of two of the locomotives is consumed, one in opposing another of equal power, as in the case of the battery referred to.

"We may, indeed, use the same homely illustration in a variety of ways to show the action of electricity on a wire.

"We have heretofore spoken of the *current* or *flow* of electricity when we have meant to signify the *direction* in which the electricity *acts*. Thus, we have said that when the positive pole of a battery is placed to the line its action is invariably toward the line, as shown by a galvanometer, and the action of a negative pole when placed to the line is as invariably inward from the line.

"Now, if we say that when a locomotive is pushing the train it is exerting a positive strength, it is easy to understand that if we cause the engine at one end of the train to exert a positive and the one at the other to exert a negative strength upon the train, there will be the full effect of two engines acting upon the train in the same direction, and the train will move accordingly.

"On the contrary, if we cause both to exert a positive strength, or both to exert a negative strength upon the train, that is to say, if we cause them both to push or both to pull the train, it will move.

"Thus it is, practically, with electric batteries at each end of a wire, with regard to their effect on electro-magnets."

IV.—CABLE TELEGRAPHY.

In ordinary telegraph systems the line wire or conductor is suspended in the air by being attached to insulators that are supported on poles. In some cases, however, the conducting wire is buried in the earth or placed under water. In such cases, since the conductor, if bare, would touch the earth at all parts of its length, it must be thoroughly insulated throughout its entire length. The conductors or wires are generally placed in the form of a cable. Cables are sometimes suspended in the air like the bare wires in ordinary systems. Aerial cables generally consist of numerous wires bunched together.

There are three varieties of cables, namely:

(1.) Submarine cables.

(2.) Subterranean cables.

(3.) Aerial cables.

A cable consists generally of two or more insulated conductors surrounded by an insulating material, and covered externally in most cases by a metallic sheathing or armor.

The word cable is sometimes applied to the case

of a single conductor or line wire when provided with an insulated covering and a protective armor, or sheathing. An electric cable consists of the following parts, namely :

(1.) The conducting wire or core.

(2). The insulating material placed around the wire or core.

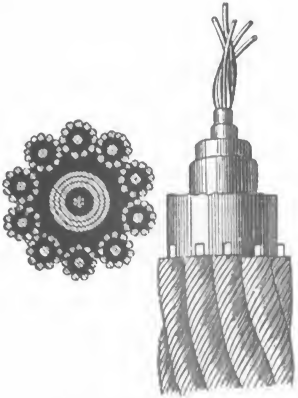

FIG. 24.—SUBMARINE CABLE.

(3). The armor or protecting covering, which consists either of strands of galvanized iron wire or of a metallic coating or covering of lead.

The general construction of a submarine cable, and the relative arrangement which the above parts

bear to one another, will be seen from an inspection of Fig. 24.

Sometimes a cable consists of a number of separately insulated conductors covered by a layer of lead. Two forms of such cables are shown in Fig. 25.

Where the cable contains more than a single wire or conductor, as is usually the case, it is called technically a bunched cable.

Various methods are adopted for disposing or arranging the separate wires or conductors in a

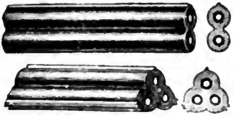

FIG. 25.—LEAD-COVERED CABLES.

bunched cable. They may be disposed or laid-up, straight-away, or twisted.

In a straight-away bunched cable, the separate conductors extend in the direction of the length of the cable without any twisting, and are placed in successive layers over one another.

In a twisted bunched cable the separate conductors instead of being placed in successive layers are twisted. In such cases each pair of conductors, which acts as a metallic circuit, is twisted separately,

the separately twisted pairs being placed in successive layers.

A twisted bunched cable is suitable for telephone purposes since it possesses the advantage of avoiding those effects of induction that are so disadvantageous to such circuits.

In laying-up the twisted pairs in successive layers in a bunched cable the direction of the twist is reversed in each successive layer.

Before a telegraph line can transmit a signal to its furthest end its difference of potential must be raised to an amount depending on the character of the instrument, the nature of the system and the length and nature of the line; or, in other words, the line must receive a certain charge before a current sent into it at one end can produce a signal at the other end.

The amount of this charge will depend on the length of the line wire, the extent of its surface and on its neighborhood to the earth, or to other wires or neighboring conductors. The charge which must thus be given before the signals can be transmitted is lost as a current for signaling. The greater the electrostatic capacity of the line wire, the greater will be the loss, and the greater also will be the retardation in signaling.

By the term retardation, as used in signaling, is meant a decrease of speed in telegraphic signaling, caused among other things either by mutual induction between the conductor and a neighboring conductor, by condenser action, or by magnetic inertia or lag or the time required to magnetize or demagnetize the core of the electro-receptive devices used on the line.

The retardation in the speed of signaling is especially marked in the case of cables, on account of the high electrostatic capacity of gutta-percha, which insulates the conductor from the surrounding media, causing the cable to act as a condenser. From this and other causes the retardation produced in cables is very marked, especially in submarine cables. In order to diminish these effects, exceedingly small currents are employed.

According to Culley, the retardation in the case of one of the submarine cables between Newfoundland and Ireland is so great that two-tenths of a second elapse before a signal sent from one end of the cable produces any appreciable effect at the other end, while three-tenths of a second are required for the current through the cable to acquire its full strength.

To detect the very small currents or impulses em-

ployed in cable telegraphy, exceedingly sensitive instruments are required at the receiving ends of the line.

Since the currents employed in submarine telegraphy are exceedingly weak, the disturbing effect of earth currents must be carefully avoided. Earth currents arise from the fact that different parts of the earth are frequently at different potentials, and, when such points are connected by means of a conductor, an electric current results. In long land lines the bad effects of the earth currents can be prevented by means of metallic circuits, in which no earth connection is employed. In submarine cables these effects can be partly avoided by the use of condensers, in which case the line is maintained on an open or broken circuit. In such cases, one pole of the receiving instrument or galvanometer is connected with one side of the condenser and its other terminal with the earth. The other side of the condenser is connected to the line wire or conductor. When a current is sent into the line, the charge which accumulates on the condenser plates connected with it, produces by induction an opposite charge on the plates connected with the galvanometer. This causes a deflection of its needle. In practice condensers are generally placed at each end of the line.

Short cables may be worked by means of Morse apparatus. Long cables are generally worked by means of the deflections of a magnetic needle or by means of a siphon recorder, the operation of which is described in another part of this primer.

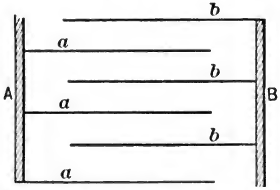

FIG. 26.—METHOD OF CONSTRUCTION OF A CONDENSER.

The condenser employed in cable telegraphy is made in a variety of ways. A convenient way is that in which sheets of tin-foil *b, b, b,* and *a, a, a,* are placed between sheets of oiled silk or mica, one set of alternate sheets *b, b, b,* being connected to one of the brass pieces *B*, Fig. 26, and the other set of sheets *a, a, a* to the other brass piece *A*. In order to vary the size of the condenser, the coatings are divided into separate parts, so that either all or any part or parts of the condenser may be introduced into or removed from the circuit by the use of the plug keys.

The form of condenser shown in Fig. 27 is capable of division into five separate values, namely, .05, .05, .2, .2, .5 microfarad.

The condensers employed in long cable lines have a capacity of about 20 microfarads, which is equivalent to the capacity of about 60 knots of an ordinary submarine cable.

The receiving instrument formerly employed in cable telegraphy on long cables was a Thomson reflecting galvanometer, or some modification thereof.

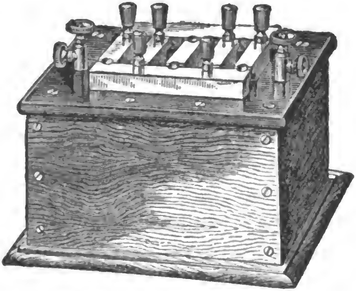

FIG. 27—STANDARD CONDENSER.

This instrument is now generally replaced by the siphon recorder or some modification thereof.

When the reflecting galvanometer is employed, as the impulses are received over the line, the needle is given a motion toward the right or left, which corresponds to the characters or letters of the Morse alphabet. The movements of the needle are generally observed, not directly, but by the movement of

a spot of light reflected from a mirror attached to the suspension system.

A deflection of the needle to the left corresponds to a dot; a deflection to the right to a dash.

	Printing	Single Needle		Printing	Single Needle
a	.—	\/	n	—.	/\
b	—...	/\\\	o	———	///
c	—.—.	/\/\	p	.——.	\//\
d	—..	/\\	q	——.—	//\/
e	.	\	r	.—.	\/\
f	..—.	\\/\	s	...	\\\
g	——.	//\	t	—	/
h	....	\\\\	u	..—	\\/
i	..	\\	v	...—	\\\/
j	.———	\///	w	.——	\//
k	—.—	/\/	x	—..—	/\\/
l	.—..	\/\\	y	—.——	/\//
m	——	//	z	——..	//\\

INTERNATIONAL TELEGRAPHIC CODE.

The characters employed in this system are shown in the accompanying table, contrasted with the Morse characters as used in the recording instruments employed in Europe generally. The characters are the same as in the American Morse, with the exception of those characters of the American Morse in which spaces are employed between the dots and dashes.

In the modification of the mirror galvanometer that is employed in the cable lines extending between

England and America, or India, the mirror and deflecting magnet have been reduced to the small weight of but two or three grains. A dead-beat action has been obtained in this mirror; that is, the mirror moves rapidly to its position and at once comes to rest without swinging to-and-fro. This dead-beat action has been obtained by means of a very short suspension system and a powerful deflecting field. The resistance of the coil of the deflecting field is about 2,000 ohms.

Considerable skill and constant attention are required to correctly read the deflections of the needle from right to left. Various devices have been produced for permanently recording these movements. The most successful of these was invented by Sir William Thomson in 1867. Thomson's device consists of an apparatus by means of which a delicately poised siphon, moved to the right or left by impulses sent into the line, is caused to project a fine stream of ink on a paper fillet moved underneath it. One end of the siphon dips into ink in a vessel. The record is received on a fillet of paper mechanically moved underneath the siphon.

In the original form of apparatus the ink was discharged from the siphon by electric charges imparted to it by an electrostatic induction machine. Con-

siderable difficulties, however, arose in actual practice in maintaining this machine in operation during moist conditions of the atmosphere. By means of a recent invention these discharges have been obtained by a constant vibratory motion being given to the siphon by local means.

The details of the siphon recorder are shown in Fig. 28. A light rectangular coil of very fine insulated wire, *b b*, is suspended by a thin wire $f\,f^1$, be-

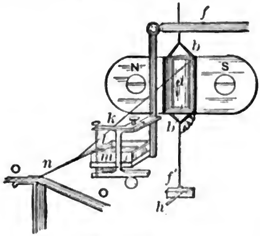

FIG. 28.—THE SIPHON RECORDER.

tween the poles of a powerful compound magnet. The coil *b b*, moves on the vertical axis of the supporting wire $f\,f^1$, which is adjustable as to tension at *h*. A stationary soft iron core *a*, which is magnetized by induction from the poles *N*, *S*, strengthens the magnetic field of *N*, *S*.

The cable current is received by the coil *b b*, through the suspension wire $f\,f'$, and is moved to the

right or left, according to the direction of the current, to an extent that depends on the strength of the current.

A fine glass siphon *n*, dips into a reservoir of ink at *m*, and is capable of movement on a vertical axis *l*, backward or forward in one direction by a silk

FIG. 29.—RECORD OF SIPHON RECORDER.

thread *k*, attached to *b*, and in the opposite direction by a retractile spring attached to an arm of the axis *l*.

As a paper fillet is moved under the point of the siphon an irregular curved line is marked thereon.

FIG. 30.—RECORD OF SIPHON RECORDER.

Two records as actually received by a siphon recorder are shown in Figs. 29 and 30. Movements upward correspond to the dots and downward to dashes.

Submarine cables have been successfully duplexed.

EXTRACTS FROM STANDARD WORKS.

The effects produced on line wires or conductors by retardation are thus described by Preece and Sivewright in their work on "Telegraphy,"* on page 133 :

"When a quantity of electricity flows through a line in the form of a current, the first portion of the current is retained or accumulated upon the surface of the wire, in the same way that a charge is retained or accumulated upon the surface of a Leyden jar. The quantity accumulated depends (1) upon the length and diameter of the wire, (2 upon its distance from the earth and (3) upon the insulating medium that separates it from the earth. Thus, in the case of a submarine cable, the conductor of which is insulated with gutta-percha or india-rubber, and is maintained in very close proximity to the earth, a very considerable charge is held by the wire. An overground wire is insulated in air, and though it is maintained at a considerable distance from the earth, yet it is in close proximity to other wires, or to buildings or trees which are in connection with the earth, and it also retains a charge. In fact, it is found in England that the charge retained by twenty miles of ordinary line wire is about equal to that

* "Telegraphy," by W. H. Preece, F.R.S., M. Inst. C.E., &c., and J. Sivewright, M.A., C.M.G. Ninth Edition, Revised and Enlarged. London and New York: Longmans, Green & Co. 1891. 396 pages, 255 illustrations. Price $2.

retained by one mile of cable of average dimensions. This power of retaining a charge is called the *electrostatic capacity* of the circuit.

"Now what are the effects of this electrostatic capacity? In the first place it absorbs all the electricity of a short momentary current and prevents the appearance of any current at the distant station. And as it absorbs the first portion of every current sent it has the same effect as if it *retarded* or delayed the first appearance of the current at the distant end. Thus the apparent velocity of the current is diminished more or less in proportion to the capacity of the circuit. In a circuit of very low capacity the current appears practically instantaneously at the distant end; but on a long or a submarine circuit there is sure to be considerable capacity and consequent retardation. Thus between Europe and America, on an Atlantic cable, the current is retarded four-tenths of a second.

"In the second place, when a current is sent through the circuit, the whole of this charge upon the wire must either be withdrawn or neutralized before a second charge of opposite sign can be accumulated upon it. This discharge may occur as a current flowing out at each end of the earth, in which case one part of the current—called the *return current*—flows back to the sending station and the other flows out at the receiving station, so *prolonging* the primary current. If one end of the wire, say the sending end, be disconnected, all the charge flows out at the distant end, and the prolongation of the current is increased. Again, the charge may be neutralized by a reverse current, which may be sent from the receiving as well as the sending end.

"Thus it is seen that the effects of electrostatic capacity is to produce *retardation* at the commencement of a current and *prolongation* at the end."

Russell, in his book entitled "Electric Light Cables,"* on page 104, speaking of insulating materials, says:

"When a generating and receiving apparatus are connected in a circuit in which a current is passing, it is necessary to insulate the conductors which form the connecting link between them, so as to prevent the current from finding any other path by means of which it can return to the generator without first passing through the receiving apparatus. This insulation may be effected by surrounding the conductor along its whole length by a material or materials offering a very high resistance to the passage of the current, such as dry air, glass, ebonite, porcelain, wood, slate, mica, silk, cotton or other fibrous materials, paper, india-rubber, gutta-percha, and a variety of oils, waxes, and resinous or bituminous compounds. Some of these, such as wood, silk, cotton, paper, etc., lose their insulating properties to a very great extent when damp; and as there is always a certain amount of moisture in the atmosphere, it is necessary to protect such substances, when used as insulators, from exposure to the air by means of a waterproof covering.

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* "Electric Light Cables and the Distribution of Electricity," by Stuart A. Russell. London: Whittaker & Co. 1892. 219 pages, 107 illustrations. Price $2.25.

Besides preventing leakage sufficient to cause an appreciable waste of energy, or to give an unpleasant shock to any one touching a part of the conducting circuit, the dielectric should be of such a kind as will allow of the insulated conductors being handled with impunity, and of sufficient thickness to prevent a disruptive discharge from one conductor to another, or from either to the earth.

"There are two distinct methods by means of which it is sought to obtain these results. In one the conductor is supported at intervals on blocks of insulating material, and elsewhere is surrounded by air; and in the other the conductor is completely inclosed in a continuous covering of insulating material. The former may appear at first sight the more advantageous, since air is a cheap form of insulator; but unfortunately the air is not as a rule dry, and the film of moisture which condenses on the surface of the insulating support (especially when the latter is itself not perfectly clean) forms a fair conductor of electricity, and thus causes the insulation of a bare wire line to be very low in damp weather when the number of supports is large. There is also the danger of a short circuit between two conductors, which may be caused by their swaying so as to touch one another, or by some conducting material falling on them so as to bridge from one to the other. The conductor being bare, it must be placed in such a position that it cannot be touched accidentally by linemen or others, unless the pressure is so low that no harm could result from a shock from it.

V.—ELECTRIC ANNUNCIATORS AND ALARMS.

An electric annunciator is a device for automatically indicating the places where electric contact points have been closed.

The character of an annunciator will depend on the nature and situation of the places at which these contact points are placed.

By the closing of contacts placed at various points in a line wire or conductor, an automatic indication is given, in a manner which will be hereafter described, of an event which has occurred at some such points, the nature of which has before been agreed upon. Attention is called to the closing of the contacts by various devices, usually by the ringing of a bell.

The electric bell that is most generally employed in annunciator systems consists of some form of automatic call bell. Automatic call bells are made in a great variety of forms. In the well-known form, shown in Fig. 31, the bell continues to ring as long as the person at the calling station continues to press the push button.

In annunciator and bell circuits generally, the circuits may be metallic throughout—that is, a metallic wire may be employed both to lead the current from the battery to the annunciator or bell and back again to the battery—or the earth may be used for the return. In such cases the gas or water pipes may be

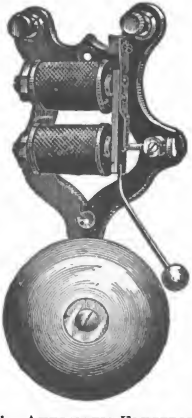

FIG. 31.—AUTOMATIC ELECTRIC BELL.

used as a return. If a gas pipe is used care should be taken to see that red-lead joints do not affect the conducting power.

The means by which the automatic opening and closing of the circuit of the bell are obtained will be

understood from an inspection of Fig. 32. The spring *c*, which supports an armature of soft iron *B*, is so placed in the circuit of the bell that when the circuit is opened, and no current is passing on the line, platinum contact points placed on the adjoining parts of *D* and *B*, touch each other. As soon, however, as the current flows through the coils of the electro-magnet, the armature *B*, is attracted to the core of the magnet, and the contacts at *D* and *B*,

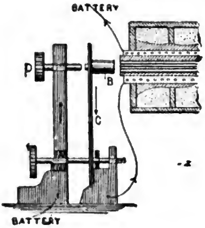

FIG. 32.—AUTOMATIC CONTACT BREAKER.

are opened, thus breaking the circuit and causing the electro-magnet to lose its magnetism. The elasticity of the spring causes the armature to fly back and again close the contact, thus again energizing the electro-magnet, attracting its armature and breaking the circuit. These makes-and-breaks follow one another with sufficient rapidity to produce a musical note. By connecting the armature of an

electro-magnet, vibrated in the manner shown in Fig. 32, to the hammer of a bell, it rings when the current passes through the apparatus.

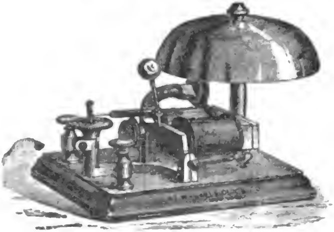

FIG. 33.—SINGLE-STROKE BELL.

In some electric bells the arrangement is such that the completion of the circuit produces a single stroke of the bell. Such a bell is called a single-

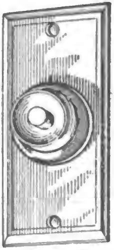

FIG. 34.—PUSH BUTTON.

stroke bell, and is shown in Fig. 33. Single-stroke bells are sometimes used for establishing communi-

cation between the station where the contact is made and the station where the bell is placed, by the use of certain agreed-on signals or by Morse characters.

The closing of the circuit at the different stations or points in the annunciator circuit is obtained by means of the well-known device of the push button, a form of which is shown in Fig. 34, in which the

FIG. 35.—AUTOMATIC DROP.

mere pushing of the button closes the contact against the action of a spring. When the finger is removed from the button, the spring automatically opens the circuit. In some forms of annunciators, however, the closing of the circuit is automatic, and is effected, as in the case of burglar alarms, without the knowledge of the party closing it.

In some cases the mere closing of the circuit causes the falling of an automatic drop, which closes the circuit and keeps it closed and the bell ringing until the circuit is opened by the replacing of the drop. A form of automatic drop is shown in Fig. 35.

Annunciators are made in a great variety of forms, which differ according to the purpose for which they are designed. The principal of these

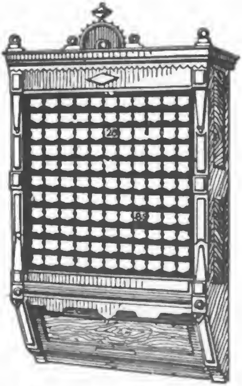

FIG. 36.—ELECTRO-MAGNETIC ANNUNCIATOR.

varieties are annunciators for hotels, houses, burglar alarms, fire alarms, temperature alarms, elevator signals, etc., etc.

Annunciators are generally operated by electro-magnetic attractions or repulsions, and are, therefore, called electro-magnetic annunciators. The automatic indication of the annunciator is obtained either by the falling of a drop or by the movements of a needle over a dial.

A form of electro-magnetic annunciator is shown in Fig. 36.

A number of electro-magnets are connected with the circuit, the closing of which it is the province of the annunciator to indicate. As the circuit connected with one of these electro-magnets is closed at the distant end, the attraction of its armature permits particular drops to fall, thus indicating the particular circuit at which the contact has been made. In the annunciator shown in figure 36, the circuits connected with the electro-magnets at 28 and 85, have been closed, as shown by the falling of the drops.

In Fig. 37 is shown a form of annunciator called a gravity-drop annunciator, in which the front has been removed to show the arrangement of the electro-magnets. Generally, only the drops are visible as shown in Fig. 36. The drops at 1, 4, 6 and 7 have fallen, the circuit with which they are connected having been closed.

These drops are restored to their former position, or set, so as to be ready for another indication on the same circuit, by a mechanical device operated by the movement of the lever shown at the left of the figure.

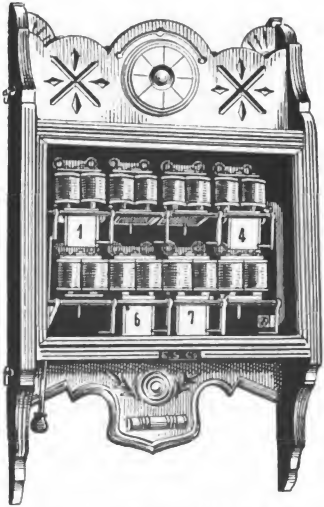

FIG. 37.—GRAVITY-DROP ANNUNCIATOR.

In Fig. 38 is shown a form of needle annunciator. When no current is passing, the needle is generally, though not always, permitted to assume a vertical

position. On the closing of the circuit, the needle is deflected and caused to assume a horizontal position. In this particular case the needles do not re-

Fig. 38.—Needle Annunciator.

quire mechanical resetting, since, as soon as the current ceases to pass, they are caused by gravity to assume a vertical position. In some cases, however,

the needle remains in a different position from that in which it is placed when no current is passing, in order to notify an attendent, who may not have heard the ringing of the bell, that a call has been made.

Fig. 39.—Elevator Annunciator.

The annunciator shown in Fig. 39 is designed for use in elevators for the purpose of signaling from different floors. Connections are made either by rolling contacts or by flexible cords, especially the latter.

In systems of burglar alarms various devices are employed by means of which the opening of a door, closet, window or safe, or the passage of a person through a room or hallway, is automatically indicated on an annunciator, and at the same time an alarm bell is thrown into action, which either continues ringing until stopped by the occupants of the house, or rings only while such contact is closed. Burglar-alarm devices consist of some mechanism

FIG. 40.—BURGLAR-ALARM ANNUNCIATOR.

for the closing of a circuit and the consequent operation of a call bell, and an indication on an annunciator of the point in the house at which the contact has been closed. The alarm bell is situated either in the house when occupied, or on the outside of the house when temporarily vacated. In some cases the alarm bells are placed in the nearest police station.

Burglar alarms are of a great variety of forms, one of which is shown in Fig. 40. The drops indicate separate stations; the clock is connected with the annunciator for the purpose of automatically disconnecting any portion of the house, during certain intervals of time. Hand switches are provided for connecting or disconnecting different circuits of the house with the alarm bell.

It is sometimes desirable to ring an alarm to notify an attendant when the temperature of the air in hothouses, incubators, tanks and buildings generally has reached a certain predetermined point. Such alarms are called temperature alarms, and are automatically operated by means of devices called thermostats.

Thermostats are devices by means of which circuits are automatically closed by the expansion of a metallic substance on its increase of temperature, and remain closed as long as the temperature of such rod is above a certain predetermined point. On the cooling of the rod its contraction automatically opens the circuit. The substance is employed in the form of a buckled plate, or of a rod of two different metallic plates that are riveted together.

Some thermostats are operated in a similar manner, by the expansion of a column of mercury. The

mercury is placed in a glass test tube, as shown in Fig. 41. One terminal of the circuit is placed directly in the mercury and the other in some portion of the tube, which will only be reached by the mercury when it has expanded a certain amount; or, in other words, when a certain temperature has

FIG. 41.—MERCURIAL THERMOSTAT.

been reached. In this case the mercury level acts as a movable contact, and as soon as it reaches the other contact point, completes the circuit through its own mass. On the subsequent contraction of the mercury the contact is automatically opened.

Somewhat similar apparatus is sometimes placed in buildings for the purpose of sounding an alarm on an increase of temperature beyond a certain point, such as would be reached if a fire were started in such building. These alarms are operated by means of thermostats and are generally sounded in the nearest fire station; or the closing of the circuit may be caused to automatically open a water tank and throw a stream of water into the room from which the alarm was sounded. Such devices are called automatic sprinklers, and are sometimes operated by the heat of the room itself, on the melting of readily fusible plugs.

In many systems of alarm or calls the mere pulling of a lever sends a call to a central office for some particular service, that it is desired such office shall render. Various devices called call-boxes are employed for this purpose. They consist essentially of means by which a succession of electric impulses are sent over a line wire at varying intervals of time. These impulses are obtained by a wheel, which is set in motion by the pulling of a lever. The impulses are received at the central station either by means of a Morse sounder or are recorded on a fillet of paper, as a series of dots and dashes, as in the ordinary telegraph recorder. The different stations signaling

are distinguished from one another, and the character of the service required indicated, by the relative duration and intervals of the impulses sent over the line; that is, by their character.

FIG. 42.—DISTRICT CALL-BOX.

Call-boxes are constructed for a great variety of purposes, the most important of which, however, are the district call-box and the fire alarm telegraph box.

In the district call-box a number of stations provided with call-boxes are connected with a central office which supplies messenger boys, or watchmen, police, fire extinguishers, or some special service that is agreed upon. The call is sent by setting the wheel in motion by pulling a lever placed on the outside of the box. In the form of district call-box, as shown in Fig. 42, four calls are provided for; namely, watchman, police, fire and special. In other forms the calls are the same, except the first, which is a messenger call.

In order to distinguish which of the services indicated by these four calls is desired, the handle is pulled until it comes opposite the letters indicating the required service and is then released. This service is indicated at the receiving station generally by the repetition of the signal required for a single call, or by some variation in the signal sent over the line, by means of the movement of an automatic break-wheel on the release of the handle.

In the fire-alarm telegraph box a similar arrangement is devised whereby on the movement of a handle, similar to that in the district call-box, alarms can be sent to a central station, or to a fire engine house situated in the district from call-boxes placed on the line.

A fire-alarm box is shown in Fig. 43, with the arrangement of its interior parts.

The closing of the contact points for the purpose of indicating the occurrence of a certain event at any point or station in a system of annunciators or alarms is sometimes obtained by the movements of a float. Such alarms are especially suitable for cases where it is desired that the level of water in a tank,

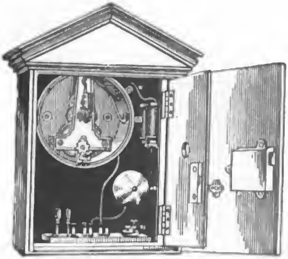

FIG. 43.—FIRE-ALARM TELEGRAPH BOX.

reservoir, or other vessel shall not exceed a certain limit. A form of water or liquid level alarm is shown at the left of Fig. 44. A float, provided with contact points, closes an electric circuit as soon as a certain level is reached, and either rings a call-bell to notify an attendant to cut off the water supply, or operates a device by means of which such supply is

automatically cut off by the action of an electro-magnet placed in the circuit of the float.

When it is desired that the level of the water shall be maintained so that it neither exceeds a certain maximum or minimum limit, and thus prevent too high or too low a water level, the device called a double float, as shown at the right of Fig. 44, is adopted.

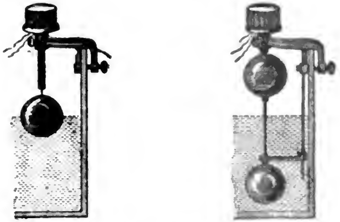

FIG. 44.—LIQUID LEVEL ALARM.

Various apparatus has been devised, by means of which the pressure of water or steam on a gauge, or the position of a mercury column in a pressure gauge, or in a thermometer or barometer, or the movement of a needle over a dial, such as in a wind gauge, aneroid barometer, or other similar instrument, is automatically recorded and registered at a distance by means of electricity. Such instruments are in general termed telemeters.

A tele-manometer is a form of telemeter for electrically indicating and recording the pressure on a steam gauge situated at a distance from the recording instrument. The tele-manometer consists of a pressure gauge furnished with electric contacts operated by the movement of the needle or the mercury column of the steam gauge. An alarm bell is provided to call attention to any variations in pressure, either as an increase above or a fall below a given or predetermined limit for which the instrument has been set.

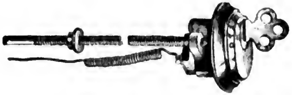

FIG. 45.—YALE LOCK-SWITCH.

The tele-thermometer and the tele-barometer are similar instruments for automatically recording at a distance the height of mercury in a thermometer or in a barometer.

In the Yale lock-switch burglar alarm, means are provided whereby the opening of a door, by an authorized party provided with a proper key, will not sound an electric alarm, but its opening by picking, or by some other key, will automatically sound an alarm. The form of such burglar alarm is shown in Fig. 45. In order to prevent the sounding of the

alarm by the use of the proper key, the different parts of the key require to be of certain exact dimensions.

Besides the above an ingenious automatic alarm has been devised whereby the current generated by a selenium cell, on its exposure to light, is made to automatically sound an alarm by closing the circuit of a local battery, which causes a bell to continue to sound until the battery is switched out of the circuit by an attendant. By its means a burglar is caused to automatically signal for an officer to arrest him. By similar means the variations in the photometric intensity of daylight or of an artificial light can be automatically recorded by means of a selenium resistance placed in the circuit of a suitable receiving instrument.

EXTRACTS FROM STANDARD WORKS.

Allsop, in his work "Practical Electric Bell Fitting," * on page 7, speaking of the earth return, says :

"Where an earth return is necessary, care should be taken to obtain a good connection. Some people seem to have an idea that any flimsy attachment, such as twisting a wire round the nearest gas bracket, is sufficient. This, though it may be simple, is by no means efficient, and as the wire rapidly oxidizes, a break in the communication occurs a day or two after the apparatus is fixed. To make a good earth connection, the following plan should be adopted: Having selected the most accessible point in the nearest water main, and scraped the pipe clean for a length of about three inches, take a piece of naked copper wire, No. 16 B. W. G., about two feet long, previously brightened with emery paper, and twist this tightly around the pipe, leaving a tail of about six inches; then solder the whole together. Now run your earth wire, which should consist of No. 16 naked copper, or $\frac{3}{16}$ galvanized wire, twisting and soldering this to the projecting tail.

"If this is properly done an excellent and lasting earth connection will be secured. Great care should be taken to see that this is not a cistern pipe, for, if so, there will be a

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"Practical Electric Bell Fitting: A Treatise on the Fitting-Up and Maintenance of Electric Bells and All the Necessary Apparatus." by F. C. Allsop. London: E. & F. N. Spon. 1891. 112 pages, 111 illustrations. Price, $1.25.

'bad earth,' caused by the break in continuity at ball-cock in the cistern.

"Should there be no water main within reasonable distance attach to the gas main, the street side of the meter (if on the house side the meter must be bridged over with a piece of wire), owing to the white and red lead used in the joints, making a very bad electrical connection. Never, if it can possibly be avoided, have the earth connection on the water main at one end, and on the gas main at the other, as permanent currents are thereby often set up.

"Should neither a water or gas main be obtainable, a pump pipe leading to a well makes a good 'earth.' Failing this, an artificial earth must be resorted to, which should be made thus: Suspend about five feet of sheet lead about six inches wide in the centre of a hole about four feet deep, then ram in with ordinary gas-coke till within six inches of surface, when fill in with soil. The earth wire must then be soldered to the projecting end of the lead. Care must be taken to obtain as moist a situation as possible for the hole"

Walker, in his "Electricity in Our Homes and Workshops,"* speaking of electric bells, says on page 122:

"Electric bells are of two kinds, those known as trembling or vibrating bells, which ring continuously as long as

* "Electricity In Our Homes and Workshops: A Practical Treatise on Auxiliary Apparatus," by Sidney F. Walker. London: Whittaker & Co. 1889. 320 pages, 127 illustrations. Price $1.50.

a current of the required strength is passing through them, and single-stroke bells, which ring once each time the circuit is completed.

"Trembler bells are used principally for domestic purposes, and occasionally for mines or fire alarms. Single-stroke bells are used for mines and railway signals, where a clear, distinct signal is of importance.

"The construction of each is nearly the same, the difference being in the form of the apparatus, and in the arrangement added to the trembler bell to cause the hammer to vibrate.

"In each there is an electro-magnet made in four parts, two limbs of round iron carrying the coils, a flat back or yoke piece, sometimes made part of the frame, to which the electro-magnet is fixed, and the movable armature with bell-hammer attached.

"In the single-stroke bell, the armature is pivoted, and either it or its hammer-shaft works between regulating screws, so that its distance from the poles can be adjusted. In some forms, as where the bell dome is carried under the electro-magnet, the pull of the latter is balanced by a spring, whose tension can be regulated, the object being to pull the armature back after striking. In those forms in which the bell dome is over the electro-magnet, a straight steel spring is usually provided for the same purpose, but it does not come into action until the blow has been struck. This form is decidedly the best. In the trembler bell, the armature is attached to a short, broad steel or brass spring, of sufficient strength to pull it away from the magnet poles when the current is not passing."

Bottone, in his work on "Electric Bells,"* thus points out and describes, on page 83, the possible defects of electric bells :

"From a careful consideration of the last two sections it will be evident that the possible defects of electric bells may be classed under four heads, namely: (1.) Bad contacts. (2.) Bad adjustment of the parts. (3.) Defective insulation. (4.) Warpage or shrinkage of base. We will consider these in the above order. First, then, as to bad contacts. Many operators are content with simply turning the terminal wires round the base of the binding screws. Unless the binding screws are held firmly down on to the wires by means of a back nut, a great loss is sure to occur at these points, as the wires may have been put on with sweaty hands, when a film of oxide soon forms, which greatly lowers the conductivity of the junction. Again, at the junction points of the wire with the contact angle brass and contact pillar, some workmen solder the junctions, using "killed spirits" as a flux. A soldered contact is certainly the best, electrically speaking, but "killed spirits," or chloride of zinc, should never be used as a flux in any apparatus or at any point that cannot be washed in an abundance of water, as chloride of zinc is very *deliquescent* (runs to water), rots the wire, and spoils the insulation of the adjacent parts. If solder be used at any parts, let *resin* be used as a flux.

* "Electric Bells and All About Them: A Practical Book for Practical Men," by S. R. Bottone. London: Whittaker & Co. 1891. 196 pages, 99 illustrations. Price $0.50.

VI.—TIME TELEGRAPHY.

A system of time telegraphy, as the name indicates, consists of any system of telegraphic communication by means of which time is telegraphed from a standard or master clock over a line circuit to a series of electric clocks placed therein, which are either entirely operated or are only regulated or set by the electric impulses thus telegraphed.

A system of time telegraphy includes the following parts, namely :

(1.) The master or standard clock, the movements of whose pendulum automatically transmit timed electric impulses to the line wire or conductor in the circuit of which the secondary clocks are placed.

(2.) A number of secondary clocks placed in the circuit of the master or standard clock, and either operated or regulated by means of timed electric impulses sent into the line wire or conductor by the movements of the pendulum of the master clock.

In some systems of time telegraphy, self-winding clocks are employed, which are corrected daily by means of correcting impulses sent into the line wire from the master clock.

The sole province of the master clock is to open and close the circuit of a voltaic battery at regular intervals. This is accomplished by the pendulum as it swings to-and-fro. The electric impulses passing through the magnetizing coils of an electro-magnet placed in a secondary clock dial produce, by means of suitable mechanism, the movements of the hands over the dial.

The secondary clock consists of an ordinary dial on which the hours and minutes are marked. The hands are moved over the dial by step-by-step movements obtained by the to-and-fro motions of the armature of an electro-magnet that is moved toward the magnet pole on the completion of the circuit through the magnetizing coils, and in the opposite direction by the action of a spring or weight. Sometimes polarized armatures are employed in secondary clocks, in which cases the motions both to-and-fro are caused by magnetic actions.

The earliest system of time telegraphy was invented by Bain. In this system, when an impulse is sent through the coils of the electro-magnet of the secondary clock, the to-and-fro movements of its armature move a pawl over the teeth of a ratchet wheel, and, on the breaking of the circuit, a spring pulls the armature back to its original position. By

proper mechanism these movements are caused to move the hands of the clock over a dial.

In Siemens' electric clock an oscillating motion is imparted to a pivoted lever, by means of which an electric current is sent into an electro-magnet at regular intervals.

In Stöhrer's system the movements of a step-by-step mechanism are obtained by means of polarized armatures.

Electric clocks may be divided into three classes :

(1.) Those whose works are moved either entirely or partially by the electric current.

(2.) Those which are only controlled, regulated or set by the electric current.

(3.) Those which are merely wound up by the electric current.

In most systems of time telegraphy the second class of electric clocks is employed.

A clock, moving independently of electric power, is regulated, or prevented from gaining or losing time, by means of a slight retardation or acceleration that is electrically imparted to its pendulum. In another form the hands are set every 12 or 24 hours to the exact time by means of electric impulses from the master clock.

A well-known form of contact-making device

for the controlling or master clock is shown in Fig. 46, in which a battery *N′ P*, grounded at its centre, at *E*, and therefore called a split battery, has its opposite terminals *P N′*, connected, as shown, to the spring contacts *S*, *S′*. By these means currents are sent into the line in opposite directions,

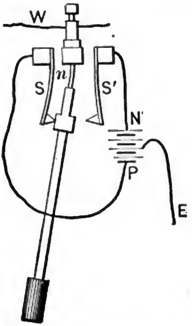

Fig. 46.—Controlling Clock.

as the contact is alternately made with *S* and *S′*, on the to-and-fro movements of its pendulum.

One way in which these electric impulses operate the controlling clock is shown in Fig. 47. The pendulum bob of the controlling clock is made in the form of a hollow coil *C C′*, so shaped that on its to-and-fro movements it encircles one of two permanent magnets *A*, *A′*, placed as shown.

When the pendulum of the controlling clock is in the position shown in Fig. 46, in contact with the spring *S*, the current passes in the direction *E, P, S, n, W*, thence through the coil *C C'*, Fig. 47, as shown, to the ground.

When, however, the pendulum of the controlling clock is in contact with the spring S', Fig. 46, the

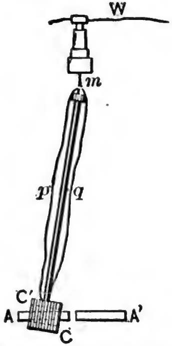

FIG. 47.—CONTROLLED CLOCK.

current flows through *W, n, S', N', E*, etc., thence through the coil *C C'*, Fig. 47, in the opposite direction, to the ground.

By these means a slight forward or backward motion is imparted to the pendulum, which is thus kept in time, or synchronized, with the motion of the controlling clock.

In some cases the pendulum, as it moves to-and-fro, makes contacts by mercury surfaces instead of by the springs S, S'.

In some forms of clocks induction currents are employed instead of the current direct from a voltaic battery.

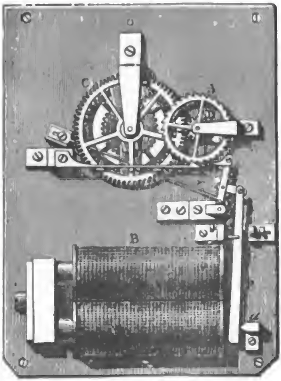

FIG. 48.—SECONDARY CLOCK.

In some systems of time telegraphy, the secondary clocks, besides being electrically controlled by the master clock, have devices connected with them by means of which they are correctly set at certain intervals during the day, either automatically by peculiar impulses sent out by the standard clock, or

by means of a telegraphic key operated by hand by an observer at an astronomical observatory.

A secondary clock, operated by means of a step-by-step motion, is shown in Fig. 48.

In the Spellier system of time telegraphy, the electric clocks are provided with a series of armatures *H, H,* Fig. 49, etc., mounted on the circumference of a wheel, that is rotated by means of a step-by-step motion produced by the attraction of the magnet poles of the electro-magnet *C C.*

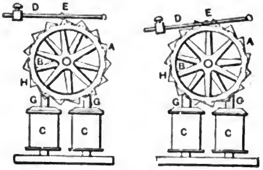

FIG. 49.—SPELLIER'S ELECTRIC CLOCK.

On the completion of the circuit, the armatures are attracted toward the magnet, and on the breaking of the circuit, are drawn away from it by the pull of a weight, placed on a lever *D,* pivoted at *E.*

A pulley at *E,* runs over the surface of a peculiarly shaped cog, placed on the escapement wheel. At the left of the drawing is seen the arrangement of the weight when the armatures are near the poles of the electro-magnet *C C,* having been at-

tracted to them on the passage of the current through the coils. In the figure to the right the position of the weight is seen as it has fallen, and the armatures are drawn away from the magnet poles so as to be ready to be again attracted when the current is again completed through their magnet coils.

In self-winding clocks, a small electric motor, usually operated by one or two Leclanché cells, is employed at regular intervals to automatically wind the clock. These times are determined by contact points that are suitably placed on some part of the clock, by means of which the circuit of a voltaic cell is closed for a sufficient length of time to permit the motor to wind the clock. Self-winding clocks, when properly constructed, need no attention whatever, save the renewal of the Leclanché or similar cells every year or so. They need, however, to be electrically controlled and regulated, unless they are themselves standard clocks.

The self-winding arrangement, however, is seldom placed on a standard clock.

In some systems of time telegraphy the correct time is indicated to an entire neighborhood by the falling of a ball termed a time-ball.

This ball is placed on a pole in some exposed position, and, by falling at some regular time, say, for

example, at 12 o'clock noon, or at sunrise or sunset, gives the time to an entire neighborhood, and thus permits the people therein to regulate their clocks.

Time-balls are generally operated in some such way as the following: A standard clock is arranged so as to complete its circuit by means of a contact spring. When the hands of the clock have reached the time at which the ball is to be dropped, an electric circuit is closed, and the current passing through the magnetizing coils of an electro-magnet placed on the pole which supports the ball, attracts its armature and releases a trigger, which thus permits the ball to fall. The time-ball is usually made as a light hollow ball formed of any suitable material. Its too sudden fall is prevented by a piston moving in an air chamber, which operates like an ordinary dash-pot.

Sometimes, in place of the time-ball, the movement of an armature of an electro-magnet pulls a trigger and fires a gun called the time-gun.

In some systems of time telegraphy, the correct time is telegraphed or telephoned from a central station or observatory to a number of subscribers, placed in the circuit of line wires or conductors, by means of impulses which are received by the subscriber as a

series of sounds at certain intervals, so that a person at a station connected with the central observatory, can, by listening at the sounder, tell the exact time of day, and so can use this knowledge for regulating any number of time pieces. This system is extensively used in large cities in nearly all large clock and watchmaking establishments.

Another species of time telegraphy is found in various systems by means of which electric clocks have their circuits connected with annunciators. By these means the movements of the hands or the works of the clock are caused, at certain predetermined times, to close electric contacts that ring bells, release drops, trace records and perform other similar work.

One of the simplest ways by which an ordinary clock can be arranged to ring a bell at certain predetermined times, is to place on the arbor or axis of the hour-hand a small wheel formed of some non-conducting material, except at one point of its circumference. This small piece of conducting material is made to extend through to the metal of the arbor, or is placed in electrical connection with such metal by means of a conducting wire.

By making this wheel fit the axis fairly tight, it can be moved around so as to be readily set at any

required point on the axis of the hour hand corresponding to the time at which it is desired that the clock shall automatically ring the alarm bell. A flat spring, insulated at its base, rests on the surface of the wheel so as to be moved over it on the motion of the arbor.

When the hour hand of the clock reaches the point at which the contact point is set, connection is made with the battery by the metal spring resting on the contact point and the bell rings as long as the contact point remains on the spring.

It will be readily seen that the time during which the bell will continue to ring will depend on the distance that the contact piece extends circumferentially around the wheel.

In order to prevent the bell from ringing for too long a time, a second contact piece is sometimes placed on the arbor of the minute hand, and the connections so made that the circuit is closed or completed only while the minute and hour hand make contact together; that is, while the minute hand is crossing the hour hand.

In certain cases it is desirable to obtain a permanent record of the time during which a given event occurred. If, for example, a watchman is directed to visit each of a number of different stations in the

district or building he is watching, it is desirable that a record of such visits should be made in some locality not accessible to the watchman. An apparatus of this kind is generally called a watchman's register.

Watchmen's registers are made in a great variety of forms; they generally, however, consist of a cylinder or disc driven by clockwork, and covered by a sheet of paper on which various marks are made by styluses or pens, or punches, that are operated by means of electro-magnets, on the closing of an electric circuit by the pressing of a push button, or by the closing of a key by the watchman at each station he is required to visit.

Besides the use of electricity for measuring the duration of time throughout the day, as in an ordinary clock, it can also be employed to measure such exceedingly minute intervals of time as would be required for a rifle ball to pass through the distance of a foot or an inch.

The method generally employed for such purposes is by means of the movements of a pendulum. The time required for such pendulum to make one complete swing to-and-fro depends on the length of the pendulum.

When the intervals to be measured are exceedingly

minute, the movements of such pendulum should be exceedingly rapid. In such cases the ordinary pendulum is replaced by a tuning fork or bar of steel, whose rate of motion is accurately known. An apparatus for automatically registering small intervals of time is called a chronograph.

Chronographs, though of a great variety of forms, generally register very small intervals of time by causing a vibrating tuning fork, whose rate of motion is known, to trace a sinuous line on a smoke blackened sheet of paper placed on a cylinder driven at a uniform rate of motion by clockwork. If the rate of motion of the fork is accurately known, as can readily be ascertained by reference to the musical note emitted, the time that has elapsed between any two waves or sinuosities in the wave-line can be readily calculated.

Suppose, for example, a tuning fork produces 256 vibrations per second. Then, since the fork moves to-and-fro 256 times every second, there will be produced on the surface of the moving cylinder, in every second that the fork is vibrating, 256 sinuosities in the wave-line.

Suppose now the armature of an electro-magnet is so placed, as regards the surface of the smoke-blackened cylinder, that its movement, either by

opening or closing the circuit of its coils, permits it to make marks on or near to the sinuous line at the beginning or at the end of any particular observation.

Suppose that in a given observation but one of these sinuosities was included between the beginning and end of the observation; then the interval was clearly equal to 1-256 of a second.

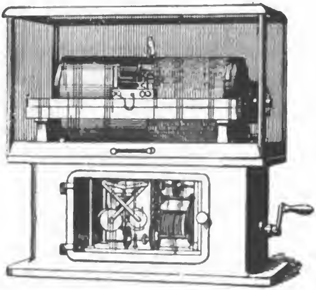

FIG. 50.—ELECTRIC CHRONOGRAPH.

If the movement of the cylinder bearing the sheet of smoke-blackened paper is made sufficiently rapid, the length of one of these sinuosities is such as will readily permit it to be divided into 100 parts. The length of each of these parts would, therefore, be 1-25600 of a second.

Of course it will be readily seen that by employing a tuning fork whose rate of vibration is greater, say, for example, 1,024 per second, and driving the cylinder that bears the smoke-blackened paper at a more rapid rate, that much smaller intervals of time can be readily measured.

In the form of electric chronograph shown in Fig. 50 an electro-magnet carrying a pen is supported on a carriage that is moved by clockwork over a sheet of paper wrapped on the surface of a rotating cylinder.

A clock is so connected with the circuit of an electro-magnet that it makes or breaks such circuit at the end of a regular interval, say, for example, at the end of every two seconds, and so makes, by means of the movements of the armature, an elevation or depression in the otherwise sinuous line that would be drawn on the paper by the double motion of the rotation of the cylinder and the movement of the pen-carriage.

Suppose, now, it is desired to know with great precision the exact time of any occurrence, such, for example, as the transit or passage of a star over the meridian. The observer, who carries a key or a push-button in his hand, opens or closes the circuit of an electro-magnet at the exact moment of

the observation and so superposes an additional mark on the sinuous line.

Since the exact time of starting the clock and the interval between the regular successive marks are known it is easy to determine, by the distance between any two such marks, the exact time at which the additional mark was superposed. Fig. 50, taken from Young, shows a form of chronograph suitable for such purposes.

EXTRACTS FROM STANDARD WORKS.

Prescott, in Vol. II. of his work on "Electricity and the Electric Telegraph,"* in speaking of the electric time service as operated in New York City, says on page 1,030:

"The central regulator is stationed in the Western Union Telegraph Company's building, and is so constructed as to keep time with the highest attainable accuracy. In addition, it is every day compared with the clock of the National Observatory, at Washington, and checked by the daily time observations made at the observatories at Allegheny City, Pa., and Cambridge, Mass., with which it is in telegraphic communication. By this it must not be inferred that the clock in question is kept in exact accord with either or all of the observatory clocks, that being a mechanical impossibility. The range of variations, however, is kept within a few hundredths of a second. It is possible to measure and record the hundredth part of a second. Fig. 605 will make clear how it is done. It shows a section of the paper tape of the chronograph, which is used in comparing the standard clock of the Washington observatory.

"The chronograph is electrically connected to both clocks, and records the pendulum beats of each on the strip

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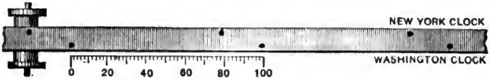
*"Electricity and the Electric Telegraph," by George B. Prescott. New York: D. Appleton & Co. 1892. 2 vols., 1,221 pages, 722 illustrations. Price, $7.00.

of paper. If the beats are exactly synchronous, the dots stand side by side. If the beats are not synchronous, the dots will be separated by an interval, long or short, according to the difference of the clocks—that is, the difference in time between the beginnings of corresponding beats—the speed of the chronograph. Supposing the clock to be beating seconds, and the chronograph to discharge an inch



of tape each second, it is obvious that the dots recording the beats of each clock will stand one inch apart. It is obvious, too, that the lineal space between the recording dots of two clocks not beating exactly together can easily be measured, as shown by the scale placed below the dots in the cut (Fig. 605), and thereby the difference in time exactly determined."

VII.—THE TELEPHONE.

A telephone is any apparatus by means of which the effects of either articulate speech or musical sounds can be transmitted from one end of a line wire or conductor to either the other end, or to some intermediate point thereon, where they are correctly reproduced.

Telephonic apparatus for the transmission of speech consists essentially of transmitting apparatus into which a speaker talks, and receiving apparatus at which a correspondent listens. The conversation is carried on through a line wire or conductor from either end of the line, or from intermediate points thereon, by means of transmitting and receiving instruments suitably connected therewith.

The articulating telephone was invented by Reiss, in Germany, in 1861. From the difficulty of adjusting Reiss' apparatus it never came into extended use. In 1876 Bell produced in America a telephone which was rapidly and widely introduced.

In order to understand the principles of operation of the telephone it will be necessary to inquire some little into the causes and phenomena of sound.

There are three characteristics of sound; namely, tone, or pitch; intensity, or loudness, and quality, or timbre.

Sounds differ from one another in tone or pitch by reason of a difference in the number of the to-and-fro motions or waves, which they produce in the air around them; or, in other words, by reason of a difference in the rapidity with which such waves follow one another.

Sounds differ in loudness or intensity by reason of differences in what is called the amplitude of the waves; that is by differences in the amount of energy acting on the medium to produce the to-and-fro motions or waves that take place in it.

By the timbre or quality of a musical sound is meant that characteristic by means of which sounds of the same tone and intensity, when sounded on different instruments, such for example as C, on the flute, and the same C, on the violin, can be readily distinguished from one another. Differences in quality arise from the fact that what are generally called single notes or tones, almost always consist of assemblages of different tones, or are in reality chords. In such assemblages of tones there is one whose intensity is so much greater than the others that it is the only one which is ordinarily heard. With it, how-

ever, are associated a number of additional but feebler tones generally called over-tones. It is because the over-tones which accompany the note C, as sounded on the flute, differ both in pitch and relative intensity from those which accompany the same note C, when sounded on the violin, that we are enabled to distinguish the note of the flute from the note of the violin, although the pitch and intensity of the two notes are the same.

When a bell is struck, the sound it produces is carried to the ear of a listener by means of waves, or to-and-fro motions, which the bell makes in the air around it.

When the sound waves follow one another with a certain rapidity and enter the ear of a listener, they produce movements or shakings therein of the same rapidity as the waves themselves. Being carried by the mechanism of the ear to the brain, these vibrations cause a sensation of sound, which varies with the character of the exciting waves.

There are various kinds of articulating telephones. These, however, may be divided into two classes:

(1.) Those in which the sound waves produce electric currents, which, when transmitted over a line wire or conductor, produce in the receiving instrument at the other end of the line sounds of

exactly the same character as those which produced them.

(2.) Those in which the sound waves do not produce electric currents, but merely produce, in the strength of the current furnished by a battery or other electric source, variations or modifications corresponding to differences in the sound waves, which electric currents being transmitted over a line

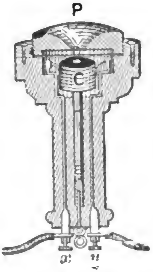


FIG. 51.—TELEPHONE.

wire or conductor reproduce in the receiving instrument the exact sounds which modified them.

The magneto-telephone is an instrument of the first class; the electro-magnetic telephone is an instrument of the second class.

Fig. 51 shows the construction of Bell's magneto-telephone. In this form of instrument the receiving and transmitting instruments are identical.

A coil *C*, of insulated wire, is placed on a core of magnetized steel, opposite the centre of a circular diaphragm of comparatively thin sheet-iron, rigidly supported at its edges. One end of the coil is connected to the line wire and the other is either connected to the earth or to the other end of a metallic circuit.

These connections are better seen in the circuit shown in Fig. 52, which is represented as being broken at *a*, to indicate a great length of wire. If a person at one end of the line, as at *D*, speaks into

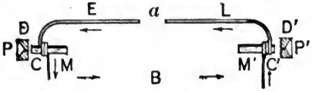


FIG. 52.—TELEPHONE CIRCUIT.

the mouthpiece *P*, of the receiving instrument, the to-and-fro motions of the sound-waves cause the sheet iron diaphragm to move toward and from the magnet *M*. This diaphragm, however, being made of soft iron, becomes magnetic by induction, and, as it moves from and toward the coil *C*, on the magnet *M*, its lines of force cut the wire of such coil and produce differences of potential therein, in accordance with the well known principles of electro-dynamic induction.

The currents produced by these differences of

potential pass over the circuit *E L*, in one direction as the diaphragm moves toward the coil *C*, and in the opposite direction as it moves away from it. Such currents passing over the line and flowing through the coil *C'*, on the receiving instrument, at the end *D'*, exactly reproduce in its diaphragm the movements of the diaphragm at the end *D*. A person whose ear is placed at the mouthpiece *P'*, will, therefore, hear all that is said or spoken at *D*. It will be observed that there is no electric battery or any source of electricity about the magneto-electric telephone. When not in use it possesses no more electricity than a dynamo does when it is not running.

The magneto-telephone is in reality a species of dynamo-electric machine. The energy required to drive it is furnished by the speaker's voice, and the receiving instrument is a species of electric motor, which reproduces in its diaphragm all the motions of the diaphragm at the transmitting end.

In actual practice it has been found more convenient to replace the permanent magnets by electro-magnets through the magnetizing coils of which the current from a voltaic cell flows. Such telephones are called electro-magnetic telephones.

In the electro-magnetic telephone the to-and-fro

motions of the diaphragm of the transmitter, caused by a speaker's voice, are employed to vary the resistance of a button of carbon, or some other variable contact resistance, placed in the circuit of the transmitter by means of variations in the pressure to which it is subjected. This variable resistance is so placed in the circuit of a voltaic cell that, on speaking into the transmitter, the current through the line is caused to rapidly vary in strength. The currents passing through the magnetizing coils on the core of the electro-magnet of the receiving instrument, produce movements in its diaphragm exactly similar to the movements of the diaphragm of the transmitter. A person listening at the receiving instrument will hear all that is spoken into the transmitting instrument.

A transmitting and receiving instrument with call bell and box for voltaic cell is shown in Fig. 53, as they are generally arranged in the United States. The instruments are placed on a vertical board suitably supported on a wall. The transmitting instrument is placed near the middle of the board. The mouthpiece shown in Fig. 53 partly covers a diaphragm, the movements of which are caused to compress a button of carbon and thus alter its electrical resistance. This button, being placed in the

circuit of a voltaic battery, causes the strength of current, which flows through such circuit, to vary with the variations in the resistance of the carbon button.

The receiving telephone is placed at the upper left-hand corner of the supporting board. A call

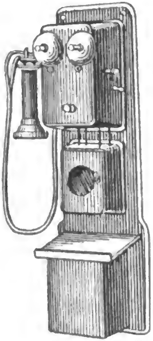


FIG. 53.—TELEPHONE APPARATUS.

bell, placed at the top of the board, serves for calling a correspondent to the telephone.

In all telephone systems there is a system of exchange whereby the different subscribers can communicate with one another. Such an exchange system consists of a combination of circuits, switches and other devices, by means of which any one of a number

of subscribers, connected with a telephone circuit, or a neighboring telephonic circuit or circuits, can be placed in electrical communication with any other subscriber, connected with such circuit or circuits.

The apparatus in a telephone exchange consists essentially of a multiple switchboard, or a number of multiple switchboards, furnished with spring-jacks, annunciator drops, and suitable connecting

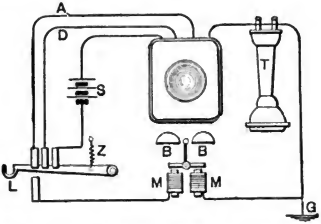


FIG. 54.—AUTOMATIC TELEPHONE SWITCH.

cords. A call-bell, or bells, is also provided. The annunciator drops are often omitted.

The arrangement of the telephone circuit as generally used in the United States will be understood from an inspection of Fig. 54. This arrangement of the circuit ensures an automatic transference of the main line from the circuit of the call-bell to the telephone circuit. This is effected by what is known as an automatic switch.

When not in use, the telephone is hung on the hook *L*, which it depresses by its weight. When removed from the hook, so as to be readily placed to the ear of a listener, the lever *L*, is pulled upward by the action of the spring *Z*, thus making the contacts whereby the local battery *S*, is closed in the circuit of the transmitter, and the telephone is disconnected from the circuit of the call-bell *M B*, and connected with the circuit of the transmitter. The line wire from the exchange is connected to one end of the lever *L*.

On being replaced on the hook *L*, the weight of the telephone depresses the lever and by breaking connections, establishes contact with the call-bell circuit.

The telephone is connected to the line wire or conductor by means of a flexible cord, so as to enable it to be readily moved and placed in any position most convenient to the listener. Flexible cords, suitable for such purposes, are shown in Fig. 55.

Shortly after the introduction of the telephone, Prof. Hughes made an invention of an instrument called the microphone, by means of which faint sounds could be rendered audible at considerable distances from where they were made.

A microphone consists essentially of a variable con-

tact operated by the sound waves it is desired to intensify and reproduce at a distance. A microphone is in reality a form of variable-contact transmitter, and experiments with various instruments devised by Hughes and others have shown that such microphone transmitters can be varied to a great extent.

The microphone depends for its operation on variations produced in the resistance of a loose con-

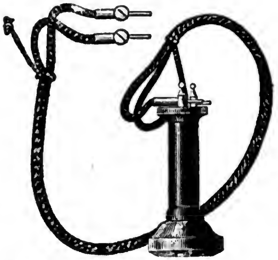


FIG. 55.—TELEPHONE CORDS.

tact by the sound waves. The loose contact, being placed so as to form part of an electric circuit, produces corresponding variations in the diaphragm of a receiving telephone.

The loose contact may take a variety of forms. One of the earlier forms given to it is shown in Fig. 56, in which a small piece of carbon *E*, pointed at both ends, is inserted in holes in the ends of carbon

cross bars *C* and *B*. A thin upright board *A*, which serves as a support for the carbons, acts as a sounding board or diaphragm. Even the walking of a fly over the sounding board can be distinctly heard in a distant receiving telephone.

Nearly all forms of variable-contact transmitters are varieties of microphones.

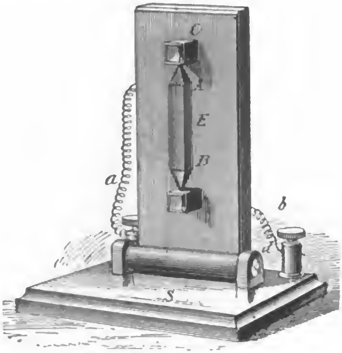


FIG. 56.—MICROPHONE.

The rapidly varying or undulatory currents that are sent through a telephone circuit, during the transmission of articulate speech, can be automatically reproduced and intensified and sent through another circuit by means of a device called a relay.

Such a relay employs a minute microphone or a

number of minute microphones as transmitters. The ease, however, with which telephonic communication can be carried on over great distances has prevented the telephone relay from coming into extended use.

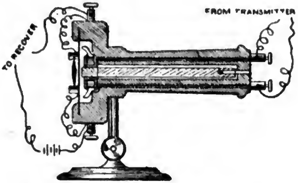


Fig. 57.—Microphone Relay.

In the form of microphone relay shown in Fig. 57 one or several minute microphones are mounted as shown on the diaphragm of the telephone whose message is to be repeated. These microphones, which

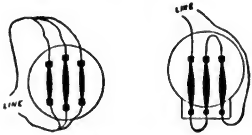


Fig. 58.—Microphone Relay.

may be connected either in series or multiple-arc in the manner shown in Fig. 58, so vary the resistance of the circuit of a local battery, that is placed in the

circuit through which the dispatch is to be automatically repeated, as to correctly repeat whatever movements have been produced by the diaphragm of the receiving telephone.

Telephones have been constructed in a great variety of forms, and operated in a great variety of ways. In all, however, the general principle is the same; namely, the voice of the speaker either produces electric currents or modifies electric currents that are produced by some suitable source.

In the Edison loud-speaking telephone the diaphragm of the receiving instrument is made of mica, or other elastic material, which receives its to-and-fro motions on the principle of the electro-motograph.

In the electro-motograph the friction of a platinum point against a rotating cylinder of moist chalk, or other suitable substance, is reduced by the passage of an electric current through it. This decrease in the friction results from an electrolytic action produced by the current.

The general construction of the electro-motograph, a form of telegraphic apparatus, will be understood from a study of Fig. 59, in which the lever *A*, pivoted with a universal joint at *C*, has a metallic point at its free extremity *F*, which is held with

some pressure against a strip of moistened paper by the action of the spring *S*. A fillet of paper *N*, rests on the metallic drum *G*, and is moved over it on the rotation of the drum by clockwork. A spring *R*, acts to move the lever *A*, in a direction opposite to that in which it tends to move by the rotation of the drum *G*.

The main battery *L*, has its negative pole connected to the point *F*, and its positive pole, through

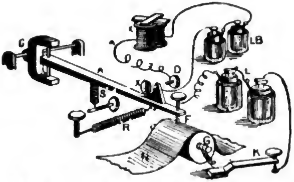


FIG. 59.—ELECTRO-MOTOGRAPH.

the key *K*, to the metallic drum *G*. The local battery *L B*, is connected through the sounder *X*, to the contacts *D* and *X*.

When the key *K*, is open, the friction of the point *F*, on the paper *N*, is sufficient to move the lever *A*, to the right so as to close the circuit of the local battery; but when the key *K*, is depressed the current of *L*, passing through the paper, decomposes the chemicals with which it is moistened, lessens the

friction of the point *F*, and permits the spring *B*, to draw the lever *A*, to the left, thus opening the circuit of the local battery *L B*.

The movements of the key are therefore reproduced by the armature of the electro-magnet *X*.

Edison applies the principles of his electro-motograph to the production of a loud-speaking telephone as follows :

A straight lever, which forms a part of the line circuit, is rigidly attached to one end of a receiving diaphragm and rests at its other end on the surface of a moistened cylinder of chalk, which is maintained in rotation by any suitable mechanical means. Electric impulses being sent into the line wire, by the voice of the speaker talking into a transmitter of ordinary construction, produce slipping movements on the cylinder which reproduce the articulate speech in the receiving diaphragm. The reproduced speech can be made sufficiently loud to be heard all over a moderately large room.

In the electro-capillary telephone of Breguet the receiving and transmitting instruments are identical in construction. Electric currents are produced, on the movements of the transmitting diaphragm, as a result of variations in the extent of the contact surfaces of liquids in capillary tubes. These movements

modify the charges produced by the difference of potential resulting from such contacts.

A vertical capillary tube communicates at its upper end with an air space situated below a diaphragm, and at its lower end with a mercury surface on which rests a layer of acidulated water. A line wire connects the mercury reservoirs of the transmitting and receiving instruments, the remainder of the circuit being formed by another wire connecting the mercury in the upper parts of the two vertical capillary tubes.

The alterations in the contact surfaces, produced at the transmitting end by the movements of the diaphragm, cause electric impulses to pass over the line that produce similar movements in the diaphragm of the receiving instrument.

By far the most curious form of telephone is seen in an instrument called the photophone, invented by Bell, in which the telephonic transmission of articulate speech is carried on along a ray of light instead of along a conducting wire.

A beam of light, reflected from a diaphragm against which a speaker's voice is directed, is caused to fall on a selenium resistance inserted in the circuit of a voltaic battery and a telephone. The varying amount of light, reflected on the selenium from the

moving diaphragm, causes changes in the resistance of the circuit, which produce changes in the current and so cause a series of to-and-fro movements in the diaphragm of the receiving telephone similar to those impressed on the transmitting diaphragm. One listening at the telephone can, therefore, hear whatever has been spoken at the transmitting diaphragm. By such means telephonic communication can be carried on along a ray or beam of light, theoretically, through any distance.

A mere block of vulcanite, or other suitable substance, may be used as the receiver in place of a telephone, since, as has been discovered, a rapid succession of flashes of light produces an audible sound in small masses of these substances.

An invention which closely followed the invention of the telephone, and which probably resulted from a consideration of the manner in which its diaphragm transmits and reproduces articulate speech, was the phonograph. This wonderful instrument, by means of which articulate speech or sounds of any character can be reproduced at any indefinite time after their occurrence, may be fairly regarded as the most wonderful invention of Edison, who is justly celebrated for wonderful inventions.

In Edison's phonograph the voice of a speaker is

received by an elastic diaphragm, of thin sheet iron or other elastic material, at the centre of which a point of steel or other hard substance is fixed. The diaphragm, in its to-and-fro motions, is caused to indent a thin sheet of tinfoil placed on the surface of a cylinder *C*, Fig. 60, kept in a uniform motion of rotation by means of a crank at *W*. In a later form of instrument by Edison this movement is obtained by means of an electric motor.

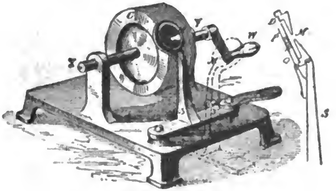


FIG. 60.—PHONOGRAPH.

In order to reproduce the sounds impressed on the tinfoil by the movements of the diaphragm, the indented tinfoil record may be placed on the surface of a cylinder exactly similar to that on which it was received; or, what is simpler and more usual, may be kept on the same surface, and the tracing point placed at the beginning of the record, against which it is maintained at a constant pressure.

If the cylinder is now rotated the point will thereby

be caused to follow the indentations of the former record, and, as it is moved up and down the hills and hollows of the record surface, the diaphragm, to which it is attached, is given to-and-fro motions that exactly correspond to the to-and-fro motions it had when impressed originally by the sounds which caused the to-and-fro movements that are recorded on the record surface. A person, therefore, listen-

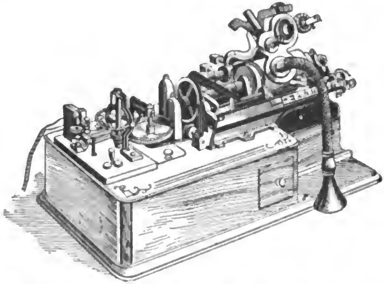


FIG. 61.—EDISON IMPROVED PHONOGRAPH.

ing at this diaphragm will hear an exact reproduction of the sounds originally uttered.

In Edison's improved phonograph, shown in Fig. 61, the record surface is formed of a cylinder of hardened wax, maintained in constant rotation by an electric motor. Two diaphragms are used, one for recording and one for reproducing the sound, ar-

ranged as in Fig. 61. The recording diaphragm is shown in position against the cylinder. This diaphragm is made of malleable glass, while the reproducing diaphragm is made of bolt silk covered with a thin layer of shellac.

A marked difference exists between the recording stylus and the reproducing stylus. The former is so shaped that a sharp gouged edge is presented to the advancing wax. The latter is ground to a small spherical end that is highly polished.

In the gramophone, an invention of Berliner, an apparatus is provided for the recording and reproduction of either articulate speech or musical sounds, on a principle similar to that employed in the phonograph.

The gramophone is based on the well-known phonautograph of Scott, in which a stylus or point attached to a diaphragm is caused to trace a record of its to-and-fro movements on the smoke-blackened surface of a cylinder maintained in relation under the said stylus.

A difference in the Berliner gramophone and the Edison phonograph is to be found in the direction in which the record surface is rotated as regards the direction in which the recording stylus performs its to-and-fro motions. In the Edison phonograph the

two motions are at right angles to each other, while in the gramophone they are parallel to each other. It is claimed that the parallelism in the case of the gramophone tends to produce much more accurate records than in the case of the phonograph, and these claims appear to be borne out in actual practice.

EXTRACTS FROM STANDARD WORKS.

In a work called "Practical Information for Telephonists,"* on page 65, Lockwood, in speaking of the disturbance experienced on telephone lines, says:

"Those who know it best regard it (electricity) as a form of energy which causes the infinitesimal particles of matter to alter their positions in regard to one another.

"The telephone, although not discovered until 1876, is based upon one of the best known properties of electro-magnetism, namely, the fact that 'when a spool of wire with a soft iron core is fixed on the pole of a permanent magnet, any alteration in the distance of an armature placed in front alters the magnetism of the core and sets up a current in the coil wound on the bobbin.'

"It is scarcely necessary at the present time to give a detailed description of the construction of the telephone, seeing that it has become, so to speak, a household word among the American people, and especially since a special chapter is devoted to the instrument itself.

"Suffice it to say, in explanation of its action, that the diaphragm of the telephone when put in motion by the voice, vibrates, approaching and receding from the core, and thereby, under the law quoted above, sets up currents

* "Practical Information for Telephonists," by T. D. Lockwood. New York: The W. J. Johnston Company, Ltd. 1891. 192 pages. Price, $1.00.

in the wire of the spool, and consequently in the line wire to which it is connected; these currents pass along the line wire, and arriving at and passing through the coil of the distant telephone, act on its diaphragm, and set up vibrations exactly corresponding to those of the initial diaphragm, and thus reproduce the original sounds.

"The currents caused by the very small movements of the diaphragm in front of the magnet are necessarily extremely feeble, so much so that the late Prof. Pierce, of Boston, compared them to those which would be produced by an electric source, of which the electromotive force should be 1-200,000th part of the power of a Daniell cell. It is, therefore, evident that the apparatus which can be distinctly acted upon by such currents must be correspondingly delicate and sensitive.

"We see, then, that the very sensibility on which the legitimate action of the telephone is so dependent becomes, under certain circumstances, positively detrimental, because it is thereby rendered equally subject to be influenced by very slight external or foreign currents; in fact by any extraneous causes which effect the electrical condition of the wire.

"As an inevitable result of this extreme sensibility to external currents, which are usually stronger than the delicate magneto-telephonic currents, the latter are to a certain extent overpowered by the former, whether acquired from the earth, or by leakage or induction from other electrical conductors; and the manifestations of the foreign currents in the receiving instrument of the telephone wire are similar to those exhibited on their legiti-

mate apparatus, while the vocal transmission is correspondingly weakened. We will now consider and endeavor to classify the different disturbing sounds heard in the telphone, and then trace them to their several originating influences."

Poole, in his "Practical Telephone Handbook,"* speaking of the necessary apparatus for use in a test-room of a telephone exchange, says on page 182 :

"All the larger telephonic exchanges should be provided with a test room, adjoining the switch room, through which all lines should pass, special provision being made for testing the lines and the detection and locating of faults with the utmost dispatch.

"The appliances which go to make up a complete test-room are as follows :

"1. *Test Board*, to which all the lines are connected, special arrangements being made for quickly connecting the testing instruments to any lines.

"2. *Lightning Arrester Board*, which often forms part of the test board.

"3. *Cross-connecting or Distributing Board*, by means of which the switch room wires may be rearranged as regards connection with the line wire leaders, still keeping all the wires tidy and regular. This distributing board really includes the test board, but it is convenient to distinguish the two.

* "The Practical Telephone Handbook and Guide to the Telephonic Exchange," by Joseph Poole. London : Whittaker & Co. 1891. 288 pages, 227 illus. Price, $1.25.

"4. *Test Clerk's Equipment*, which may be divided into two sets: (*a*) Those required for rough testing purposes, such as contacts, breaks, etc., and (*b*) those for the more delicate tests of conductivity, insulation and capacity of lines.

"5. Power generator, or pole changer, for the production of ringing currents for the use of operators. It is better to provide both these, so that one shall be available if the other fails. They should be fixed in the test room, so as to be under the observation of the test clerk in case of failure.

"The appliances will be described in the order given above, and, to render the matter as clear as possible, the author's arrangement adopted at the Manchester Exchange of the National Telephone Company, which is the most complete in this country, will be selected for description, and other systems of appliances differing from it afterward mentioned."

VIII.—ELECTROLYSIS.

It is curious how near the world may come to making a great discovery and yet miss it. I remember reading in a book published in France, sometime during the seventeenth century, an account of the claims made by an alchemist that he had solved the problem of transmuting the baser metals.

The publication referred to warned the public against him, but naïvely remarked that it was true, that by dipping a bar of iron in the waters of a certain deserted copper mine, the alchemist had actually succeeded in transmuting the iron into copper, but that this change did not extend or penetrate very far into the mass of the iron, but affected its surface only.

In the light of our knowledge of to-day the explanation of this phenomenon would seem evident; for, although perfectly pure iron dipped in certain salts of copper may have the copper deposited on it as a result of a chemical action pure and simple, yet it would appear almost certain that, under the

circumstances described, the iron bar, when dipped into a solution of a copper salt, became coated with a thin layer of metallic copper by the action of the electricity produced by the minute voltaic couples formed by the iron and the impurities present in it. The alleged miraculous transmutation of the iron by the alchemist was, in reality, an early experiment in electrolysis, or chemical decomposition effected by means of an electric current.

Besides this early knowledge of the effects of electrolysis without apprehending the cause, the following additional facts may be mentioned :

Paracelsus describes a process for coating copper and iron with silver by simple immersion in a silver solution.

Sulzer, in 1752, describes the peculiar taste, resembling that of green vitriol, produced when lead and silver, joined at one end, are placed on the tongue. Here an electrolysis occurs, though it was not then recognized.

The power of electricity to effect chemical decomposition was first intelligently recognized by Nicholson on the 2d of May, 1800, by means of a voltaic pile made of 36 silver half-crowns alternating with an equal number of discs of zinc and cloth soaked in salt water. When the terminals of this pile were

immersed in salt water, bubbles of gas were observed, and Nicholson made the discovery that an electric current possesses the power of decomposing water.

This great discovery created an intense excitement throughout the scientific world. A great many experiments were made, concerning the strange power possessed by an electric current of effecting chemical decomposition.

On the 5th of October, 1807, Sir Humphrey Davy made the memorable discovery that potash, which before this date was believed to be an elementary substance, was in reality a compound formed of the metal potassium combined with the gaseous element oxygen.

Davy did not rest satisfied with this discovery, but soon afterward proved that most of the alkaline earths and other substances, which form the greater part of the earth's crust, are formed of metallic bases combined with oxygen or other substances.

The evidence of the true elementary nature of many of the so-called elements is based mainly on the fact that they have thus far resisted all efforts made to decompose them into simpler substances. We should, however, bear in mind, that until Davy's time, potash, soda and many other similar substances were formerly believed to be elements. It is not

improbable that many of the elements, now so called, may hereafter be decomposed into simpler substances. It is indeed the belief of some scientific men that all the so-called chemical elements are formed by various combinations of a single but as yet undetected elementary substance.

When an electric current is sent through a compound liquid substance, or electrolyte, that permits the current to pass only by means of the decomposition of the liquid, it is decomposed or separated into its constituent atoms or groups of atoms or radicals called ions. These ions are of two distinct kinds; the electro-positive ions, or kathions, and the electro-negative ions, or anions.

The anions, or the electro-negative ions, appear at the anode, or at that terminal of the source which is connected with the electro-positive terminal, and the kathions, or electro-positive ions, appear at the kathode, or at the electro-negative terminal.

Suppose, for example, that an electric current is sent through a solution of copper sulphate, and that the copper sulphate is decomposed into its ions or radicals. This salt is composed of an atom of copper, which forms the electro-positive radical, or kathion, and an acid radical, SO_4, which forms the negative radical or anion. When the current passes,

an electrolytic decomposition ensues. The copper atoms, or kathions, being positive, appear at the negative electrode, or kathode; and the acid radicals, being negative, appear at the positive electrode.

It will be seen that the terms kathions and anions are given to the radicals, not according to their polarity, but according to the polarity of the electrodes at which they appear. Thus electro-positive radicals are called kathions because they appear at the electro-negative electrode or kathode; electro-negative radicals are called anions because they appear at the electro-positive electrode or anode.

A division of the chemical elements into electro-positive and electro-negative elements has been made based on the electrodes at which the different elements appear during electrolysis. Hydrogen, and the metals generally, are electro-positive, since they appear at the kathode, or electro-negative terminal. Oxygen, chlorine, iodine and fluorine are electro-negative, since they appear at the anode, or electro-positive electrode.

A vessel containing an electrolyte in which electrolysis is taking place is called an electrolytic cell. An electrolytic cell is called a voltameter when arranged to measure the strength of the current which passes by the amount of chemical decomposition effected.

The amount of chemical decomposition effected by an electric current is proportional to the amount of electricity that passes through the circuit; or, in other words, to the number of coulombs that pass; thus ten coulombs will produce exactly twice as much chemical decomposition as five coulombs; or, since one ampère per second, or one ampère second, equals one coulomb, the words ampère seconds may be used in the above in place of coulombs.

The weight of any one of the two chemical substances that are set free during an electrolytic decomposition is equal to the number of coulombs, multiplied by a quantity called the electro-chemical equivalent of the ion.

The laws of electrolysis have been expressed by Faraday as follows:

(1.) The amount of an electrolyte decomposed is directly proportional to the quantity of electricity that passes through it; that is, two coulombs will decompose twice as much as one coulomb.

(2.) If the same current is passed through different electrolytes, the quantity of each ion evolved is proportional to its chemical equivalent.

By the chemical equivalent of a substance is meant the quotient obtained by dividing the atomic weight of the substance by its atomicity; or, the chemical

equivalent of a substance is the ratio which exists between the quantity of an element and the quantity of hydrogen it is capable of replacing in combination.

Care must be taken to avoid confounding the chemical equivalent of a substance with its atomic weight. The chemical equivalent has a different value from the atomic weight whenever the valency or atomicity of the substance is greater than unity. Thus, the atomic weight of gold is 196.2, but since in *ic* compounds one atom of gold has a valency or atomicity of 3—that is, is capable of combining with three atoms of hydrogen—the weight of gold equivalent to the weight of one atom of hydrogen, or the chemical equivalent of gold, is $\frac{196.2}{3}$, or 65.4.

By the electro-chemical equivalent of a substance is meant the weight of such substance in grammes that is liberated during electrolysis by the passage of one coulomb of electricity.

The electro-chemical equivalent of a substance can readily be found by multiplying the electro-chemical equivalent of hydrogen by the chemical equivalent of the element.

It may be determined experimentally that one coulomb of electricity, expended electrolytically, will liberate .0000105 gramme of hydrogen. There-

fore one coulomb, or a current of one ampère for one second, will liberate .0000105 gramme of hydrogen. The number .0000105 is called the electro-chemical equivalent of hydrogen.

In the same manner the electro-chemical equivalents of any of the other elements is obtained by multiplying the electro-chemical equivalent of hydrogen by the chemical equivalent of that element.

In the following table the names of the chemical elements, the symbols by which they are usually expressed in chemical works, the approximate atomic weights and the chemical equivalents are given:

Names of elements.	Symbol.	Approximate atomic weight.	Chemical Equivalent.
Aluminium	Al	27.	9. [compounds
Antimony	Sb	120.	40. in *ous*, 24 in *ic*
Arsenic	As	74.9	24.9 in *ous*, 15 in *ic*
Barium	Ba	136.8	68.4
Beryllium	Be	9.1	4.6
Bismuth	Bi	207.5	69.2
Boron	B	10.9	3.6
Bromine	Br	79.8	79.8
Cadmium	Cd	111.8	55.9
Caesium	Cs	132.6	66.3
Calcium	Ca	40.	20.
Carbon	C	12.	6.
Cerium	Ce	140.4	....
Chlorine	Cl	35.4	35.4
Chromium	Cr	52.	26. in *ous*, 17.3 in *ic*
Cobalt	Co	58.9	29.5
Copper	Cu	63.2	31.6
Didymium	D	144.6	....
Erbium	E	165.9	....
Fluorine	F	19.	19.

Names of elements.	Symbol.	Approximate atomic weight.	Chemical Equivalent.
Gallium	Ga	68.9	....
Germanium	Ge	72.3	....
Glucinum	G	....	....
Gold	Au	196.2	196.2 in *ous*, 65.4 in *ic*
Hydrogen	H	1.	1.
Indium	In	113.4	37.8
Iodine	I	126.6	126.6
Iridium	Ir	192.7	96.4, 64.2, 48.2
Iron	Fe	55.9	28 in *ous*, 18.6 in *ic*
Lanthanum	La	138.5	....
Lead	Pb	206.5	103.3
Lithium	Li	7.	7.
Magnesium	Mg	24.	12.
Manganese	Mn	53.9	27.
Mercury	Hg	199.7	199.7 in *ous*, 99.9 in *ic*
Molybdenum	Mo	95.5	....
Nickel	Ni	57.9	28.
Niobium	Nb	93.8	....
Nitrogen	N	14.	14.
Osmium	Os	198.5	....
Oxygen	O	16.	8.
Palladium	Pd	105.7	52.9 in *ous*, 26.4 in *ic*
Phosphorus	P	31.	6.2 in phosphates
Platinum	Pt	194.4	97.2 in *ous*, 48.6 in *ic*
Potassium	K	39.1	39.
Rhodium	R	104.1	52 in *ous*, 34.7 in *ic*
Rubidium	Rb	85.3	85.3
Ruthenium	Ru	104.2	52.1 in *ous*, 34.7 in *ic*
Samarium	Sm	150.2	...
Scandium	Sc	44.	....
Selenium	Se	78.8	....
Silicon	Si	28.2	7.
Silver	Ag	107.7	107.7
Sodium	Na	23.	23.
Strontium	Sr	87.4	43.7
Sulphur	S	32	....
Tantalum	Ta	182.1	....
Tellurium	Te	128.	....
Thallium	Tl	203.7	203.7 in *ous*, 67.9 in *ic*
Thorium	Th	233.4	....
Tin	Sn	117.7	58.9 in *ous*, 29.4 in *ic*
Titanium	Ti	48.	24. in *ous*, 12 in *ic*
Tungsten	W	183.6	91.8 in *ous*
Uranium	U	238.5	119.2 in *ous*
Vanadium	Va	51.3	17.1 in *ous*
Ytterbium	Yb	172.8	....
Yttrium	Y	89.8	..
Zinc	Zn	64.9	32.5
Zirconium	Zr	89.4	....

* *Atomic weight* divided by the valency.

—*Houston's Dictionary of Electricity.*

It will be seen that the chemical equivalents are equal to the atomic weights divided by the valency. Thus aluminium, Al, whose approximate atomic weight is 27, has a valency or atomicity of 3. Its chemical equivalent is therefore $\frac{27}{3}$ or 9. Antimony, whose atomic weight is 120, has a valency of 3 and 5, and a chemical equivalent $\frac{120}{3}$, or 40, in *ous* compounds, or $\frac{120}{5}$, or 24, in *ic* compounds.

Suppose, now, we wish to determine the electro-chemical equivalent of potassium.

The chemical equivalent of potassium is 39.1. Its electro-chemical equivalent is, therefore, $39.1 \times .0000105 = .00041055$. By multiplying the current strength or the number of coulombs that pass, by this electro-chemical equivalent, we obtain the weight of that substance so liberated by electrolysis.

The laws of electro-chemical equivalence may, therefore, be expressed as follows: The chemical decomposition produced by an electric current when passed through different substances is proportional to the chemical equivalent of each substance, that is, to its atomic weight divided by its valency.

Thus, the atomic weight of oxygen is sixteen

times greater than the atomic weight of hydrogen. Oxygen is a diad; that is, has twice the combining power of hydrogen. The passage of a given quantity of electricity will, therefore, liberate eight times, by weight, as much oxygen as hydrogen; or, to put it in another way, the passage of a given quantity of electricity will liberate two atoms of hydrogen for every atom of oxygen. Here the passage of a given amount of electricity liberates one atom of a diad element for every two atoms of hydrogen.

The atomic weight of chlorine is 35.4. The passage of a given amount of electricity will, therefore, liberate a weight of chlorine 35.4 times greater than the weight of hydrogen; or, for every atom of chlorine it will liberate one atom of hydrogen. Here the passage of a given amount of electricity liberates one atom of the monad element hydrogen, for every atom of the monad element chlorine.

Generalizing, therefore, it appears that the passage of the same quantity of electricity through an electrolyte liberates the same number of atoms of monad elements; it liberates one-half as many of diad atoms as it does of monads, and one-third as many of triad atoms as of the monads.

On the assumption that in electrolysis each monad atom carries an equal charge of electricity, whether

it be an atom of hydrogen, chlorine, potassium, silver or mercury, then each atom of any diad element carries twice as great a charge, and each triad element three times as great a charge.

It is believed by Lodge and others that the cause of atomic attraction or chemical affinity is to be traced directly to electric charges possessed by the atoms, which charges are never lost by them. According to this idea, atoms which are capable of entering into chemical combination are oppositely charged, and chemical affinity is believed to result from the mutual attractions of the opposite electric charges, which are naturally and originally possessed by the atoms.

Lodge summarizes this hypothesis substantially as follows :

(1.) That the amount of electricity possessed by each monad atom is exceedingly small, being about the hundred-thousand millionth part of an ordinary electrostatic unit, or less than the hundred trillionth of a coulomb.

(2.) The charges being small the potential is necessarily low. Probably something between one and three volts is a high difference of potential between two oppositely charged atoms.

(3.) The nearness of the attracting atoms, how-

ever, can cause a strong electrostatic attraction between them.

(4.) That chemical affinity or atomic attraction is caused by the presence of these electric charges.

(5.) That the electrostatic force between two atoms at any distance is ten thousand million billion billion times greater than their gravitation attraction at the same distance.

The following formula will be found convenient for calculating the weight of the ions which are electrolytically separated by the passage of a given current in a given time: $W = z\ C\ t$—where W, equals the weight in grammes, z, the electro-chemical equivalent of the element or ion, C, the current strength in ampères, and t, the time in seconds.

We have seen that the energy which produces the electricity in a voltaic cell is derived from the gradual burning or oxidation of the substance forming the positive plate.

Conversely, when an electric current is sent through an electrolyte, an amount of work is done or energy expended which can be measured by the amount or weight of the metal that has been deposited. This weight, as we have seen, can readily be determined from a table of electro-chemical equivalents.

Whenever electrolysis occurs, an opposing electromotive force is set up, called the electromotive force of polarization. In order to effect electrolysis, therefore, the electromotive force must be at least as great as that of the opposing or counter-electromotive force. In the case of the electrolysis of sulphuric acid, the electromotive force must be at least as great as 1.45 volts. If the electromotive force is less than this amount, although deposition may begin, it will necessarily stop as soon as the counter-electromotive force has become equal to the electromotive force of the current causing the electrolysis.

When electrolysis is effected by means of an anode formed of the same metal as that deposited at the kathode there is, practically, no counter-electromotive force produced, and, therefore, even an exceedingly feeble electromotive force will be able to deposit copper from a solution of copper sulphate if a copper plate is made to form the anode of the bath.

It is not believed that an actual transfer of the ions takes place between the opposite electrodes during electrolysis. According to Gröthuss, the following phenomena occur during electrolytic decomposition. Assuming that each molecule inherently possesses polarity, or is formed, as we have already stated, of electro-positive and electro-negative ions, then—

(1.) Before the current passes the molecules of the electrolyte are not polarized, but point in various different directions.

(2.) On the passage of the current a polarization occurs whereby all the positive ends of the molecules are turned so as to face the negative electrode, and all the negative ends, to face the positive electrode, the mass of the electrolyte being thus arranged in polarized chains between the two electrodes.

(3.) A decomposition of these chains of polarized molecules takes place, the negative ions or radicals being liberated at the anode. The positive radicals are not, however, liberated near the anode, but are believed to enter into combination with the negative ions or radicals of the molecules next to them in the chains; and the positive ions or radicals, into combination with the negative ions or radicals of the molecules next to them, and so on throughout the entire length of the chains until, finally, the positive atoms or radicals of the last molecules in the polarized chains are liberated at the surface of the negative terminal or electrode.

(4.) A semi-rotation of the molecules in the newly formed chains takes place, in order to bring these molecules with their opposite poles facing the electrodes.

The molecules are represented conventionally in Fig. 63.

The nature of these changes will be understood from an inspection of the lines of molecules shown respectively at 1, 2, 3, 4, in Fig. 62. Clausius applies the kinetic theory of matter to this phenomenon as follows ; namely, that in all forms of matter the mole-

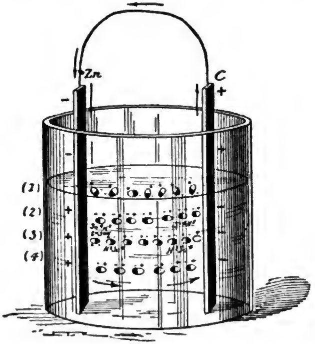


FIG. 62.—GRÖTHUSS HYPOTHESIS POLARIZATION ELECTROLYTE.

cules are in the state of movement or vibration, as supposed by Gröthuss' hypothesis ; that during electrolysis these movements are affected, and that, when the decomposition occurs, the atoms or radicals move toward the positive and negative plates respectively.

It is a curious fact that electrolysis may, under

certain circumstances, be produced by means of alternating currents.

When an alternating current is passed through dilute sulphuric acid in a voltameter provided with platinum electrodes of ordinary size, no visible decomposition occurs. If, however, the size of the electrodes be decreased below a certain point, then a visible decomposition takes place.

It has been shown that when a break occurs in a circuit of alternating currents, so that the discharge

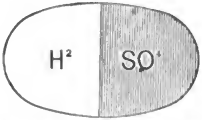


FIG. 63.—CONVENTIONALIZED MOLECULE.

passes as a spark, that visible signs of electrolysis are produced even by comparatively feeble alternating currents.

The following phenomena attend the electrolysis of sulphuric acid by means of alternating currents, namely :

(1.) The gas collected at both electrodes has the same composition.

(2.) When the quantities of electricity that alternately pass in opposite directions are unequal, the

electrodes are polarized, and, that if the electrodes are connected by a conductor, they will yield a current just as a secondary battery will.

(3.) When the quantities of electricity that alternately pass in opposite directions are equal, the electrodes manifest no sensible polarization.

EXTRACTS FROM STANDARD WORKS.

In his "Short Lectures to Electrical Artisans,"* Fleming speaks as follows on page 101 concerning the power possessed by electricity to effect chemical decomposition :

" Faraday was guided by careful investigation to the conclusion that, when a current flows, as in this case, through dilute sulphuric acid, the amount of weight of electrolyte decomposed is exactly proportional to the quantity of electricity that has traversed it. Hence if we, for instance, catch and measure the bubbles of hydrogen which come off during any time, the weight or volume of this hydrogen is exactly proportional to the number of coulombs of electricity that have passed through the liquid.

" The weight, measured in grammes, of any constituent of an electrolyte which is liberated by the passage of one coulomb of electricity is called its *electro-chemical equivalent.* If we pass one coulomb of electricity through dilute sulphuric acid and it liberates at the -- pole .000010384 gramme of hydrogen ; this number is the electro-chemical

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* " Short Lectures to Electrical Artisans: Being a Course of Experimental Lectures Delivered to a Practical Audience," by J. A. Fleming, M. A., D. Sc. London: E. & F. N. Spon. 1886. 208 pages. 74 illustrations. Price, $1 50.

equivalent of hydrogen. Instead of filling our lantern voltameter with dilute sulphuric acid, we may fill it with a solution of a metallic salt, such as acetate of lead (sugar of lead) or nitrate of silver. Putting into the trough a clear strong solution of the former salt, I now project the image of the electrodes upon the screen and pass the current. Immediately we see from the negative electrode beautiful frond-like crystals growing out. These are crystals of metallic lead. From the other pole small bubbles escape, which are oxygen. On reversing the current the crystals gradually wither away, disappear on one pole and appear on the other. If we perform the experiment with nitrate of silver we get a similar effect. If one coulomb of electricity passes through the solutions of these metallic salts, it electrolyses or extracts out from them .001118 gramme of silver or .0010716 grammes of lead respectively, and these numbers are called the electro-chemical equivalents of silver and lead. Frequently instead of using coulombs as a unit of quantity, practical men use the larger unit of the ampère-hour, which is 3,600 coulombs, and the electro-chemical equivalents per coulomb and per ampère-hour are as follows for a few metals:

	Electro-chemical per Coulomb.	Equivalent per Ampère-hour.
Hydrogen	.000010384 grm.	0.03738 grm.
Gold	.00067911 "	2.44480 grms
Silver	.00111800 "	4.02500 "
Copper	.00032709 "	1.17700 "
Zinc	.00033696 "	1.21330 "
Lead	.00107160 "	3.85780 "
Nickel	.00030425 "	1.09530 " "

"The electro-chemical equivalents of different metallic elements are proportional to these combining equivalents.

We may in a general way explain this phrase, combining equivalent, to be the relative proportions in which the metals combine with chlorine to form chlorides. Thus, one atom of chlorine is capable of combining with one atom of hydrogen, but three atoms of chlorine combine with one of gold, one atom with one of silver, and two atoms with one atom of copper, zinc, lead or nickel, and the relative combining proportions, 1, 65.4, 107.66, 31.5, 32.45, 103.2, 29.3, for the metals in order stated, and these numbers are proportional to the electro-chemical equivalents. Practically it is found that the best electrolytes for measuring quantity of electricity are either silver, zinc or copper salts."

Maycock, in his "First Book of Electricity and Magnetism,"* in speaking of the chemical effects of the current, says, on page 68 :

"The passage of electricity through certain chemical solutions splits them up into their constituents. This action of electricity is called *electrolysis* (electric analysis), and the solution which is split up is called the *electrolyte.* The current is led into and out of the solution by conducting plates of carbon, platinum, lead or other metal, according to the nature of the solution which is to be *electrolysed* The plate by which the current enters the electrolyte is called the *anode,* and the plate by which it leaves it is called

* "A First Book of Electricity and Magnetism, for the Use of Elementary Science and Art, and Engineering Students and General Readers," by W. Perren Maycock. London : Whittaker & Co. 1891. 133 pages, 84 illustrations. Price, 60 cents.

the *kathode.* The constituents into which the *electrolyte* is split up are *ions;* they are liberated from the solution at the surface of the anode and the kathode. The ion which appears at the anode is called the *anion*, and that which appears at the kathode the *kathion.* The amount of chemical action effected by the current is exactly proportional to the strength of the current and the length of time it has been passing, and is thus a measure of the quantity of electricity which has passed through the electrolyte. An *electrolytic cell* so arranged as to measure the amount of electrolysis, and therefore the quantity of electricity which has passed through, is called a *voltameter.*"

IX.—ELECTRO-METALLURGY.

Electro-metallurgy is that branch of electric science which relates to the treatment or reduction of metallic compounds by the aid of electricity. It may be divided into three branches, namely:

(1.) Electro-plating.

(2) Electro-typing.

(3.) The electrical reduction of metals from their ores, either directly by fusion, by the heat of the voltaic arc or electric incandescence, or indirectly by the electrolytic decomposition of fused masses of ore or solutions of ores.

Electro-plating is that branch of electro-metallurgy which treats of processes for covering an electrically conducting surface with a metal by the aid of electric currents.

When the process of electro-plating has been properly carried out an exceedingly thin, coherent and adherent metallic coating is obtained. By this means the commoner, oxidizable metals may be covered with a thin coating of non-oxidizable metals, such as gold or silver.

The extent of surface of an oxidizable metal that a small weight of gold is able to cover by the process of electro-plating, with a coating sufficient to protect such surface from oxidation, is so great as to appear almost incredible.

Not only can the metals be deposited by electroplating, but even the alloys of the metals can be deposited from solutions of their salts.

The process of electro-plating is generally carried on as follows: The object to be plated is thoroughly cleansed preparatory to placing it in the bath or solution containing the metals to be deposited.

The cleansing process employed must be of such a character as to insure a chemically clean surface, otherwise, the metallic deposit or coating will not be uniform in appearance, nor will it adhere firmly to the surface on which it is deposited.

The articles to be plated are successively subjected to various cleansing processes required for obtaining the requisite chemically clean surfaces. The nature of these processes will, of course, depend on the character of the surface and the nature of the material.

The first step in the cleansing process is generally effected by rubbing the surface with fine sand by means of a hand brush. The articles are then subjected to a process called scratch brushing. Scratch

brushes are made in a great variety of shapes and are provided with wire or bristles of varying coarseness. The finer bristles or wires are employed on brushes called finishing brushes. The scratch brushes are either moved by hand or are made circular in outline, so as to be used on a rotating shaft. Some forms of scratch brushes are shown in Fig. 64.

After the process of scratch brushing, the film of grease, which is very apt to be found adhering to the surface, is removed by the action of hot alkalies.

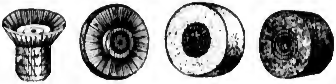

FIG. 64.—SCRATCH BRUSHES.

The articles to be electro-plated are now ready either for the burnishing process, by which their surfaces are rubbed in straight lines by tools called burnishers, of hardened steel or agate, or other similar hard materials, or they are polished by a process known as buffing; that is, they are subjected to the action of a revolving wheel covered by buff, on the surface of which rouge is spread.

After burnishing or buffing the work is rinsed in dilute acid, called dipping acid, and then washed in water and immediately placed in the bath. In some

cases after the washing in water the articles are dipped momentarily in strong acid, and are then immediately placed in the plating bath.

In all of these cleansing processes care must be taken not to touch the surfaces of the articles at any points with the fingers, since the deposits of grease thus caused will prevent the deposited metal from adhering at such points.

In order to obtain a good adherent coating of copper the mere dipping of the metallic articles in the acid of the dipping bath after cleansing is all that is required to get them ready for plating. For silver, however, the surfaces are often subjected to a process called the quickening process, which consists essentially in dipping them into quickening liquids. These quickening liquids consist of various solutions of mercury, which cover the surfaces of the articles with a very thin layer of metallic mercury.

In using quickening solutions it is necessary to permit the formation of only an exceedingly thin coating of mercury, since otherwise the electro-plated coating will be liable to strip.

In some cases articles that are to be electro-plated are cleansed by a process called fire cleansing, in which case the surfaces are cleansed by subjecting the articles to the action of heat.

When it is desired to plate only certain portions of the surface of an article, a process called stopping-off is employed. In this process the parts that are not to receive the metal coating are stopped off, as it is technically called, by covering them with some non-conducting varnish. When, for example, it is desired to cover certain parts only of the surfaces of an article with gold and the remaining parts with silver, the entire surface is electro-plated with silver, and the portions which are to remain silver-plated are stopped-off by covering them with non-conducting varnish, and the object placed in a gold bath, when the portions not stopped-off are covered with a deposit of gold.

The objects to be electro-plated, having acquired chemically clean surfaces, are now connected with the negative electrode of a battery and placed in a suitable solution of the metal with which they are to be electro-plated, opposite a plate of the same metal as is in the solution, and connected to the positive terminal of the battery or other electric source. In other words, the object to be plated is made the kathode of a plating bath, and the plate of the metal to be plated is made the anode.

Suppose, for example, the object is to be copper-plated: It is attached to the negative terminal or

kathode of an electric source and placed in a solution of copper sulphate, or cyanide of copper, opposite a plate of copper that is attached to the anode of the same source.

On the passage of the current, the copper sulphate, $Cu\ S\ O_4$, is decomposed, metallic copper being deposited in an adherent layer on the article connected with the kathode, and the acid radical $S\ O_4$ appearing at the anode, where it combines with the atoms of the copper plate.

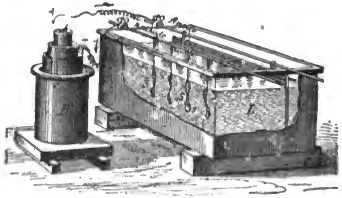

FIG. 65.—SILVER-PLATING BATH.

Since for every molecule of copper sulphate decomposed in the electrolyte, a new molecule of copper sulphate is thus formed by the gradual solution of the copper plate at the anode, the strength of the solution in the bath is maintained constant by the passage of a current as long as any of the copper plate remains undissolved at the anode.

In Fig. 65, an arrangement for silver-plating is

shown. A voltaic cell has its terminals connected with two metallic rods which form conducting supports for connection with the anode and kathode of the cell. The spoons, forks, etc., to be electro-plated are immersed in a suitable silver solution and are connected with the kathode of the cell, while the plate of silver is connected with the anode.

Various formulæ have been proposed for silver baths. Roseleur proposes a bath in which a double cyanide of silver is employed. The following are the proportions:

$H\,O_2$	1,000 parts
Cyanide of potassium, pure	50 parts
Silver, pure	25 parts

Pure silver is converted into silver nitrate by treating with pure nitric acid. The solution is heated to dryness and subsequently fused, and the fused nitrate dissolved in 15 times its weight of distilled water, and treated with a 10 per cent. solution of cyanide of potassium, by means of which silver cyanide is thrown down in the form of a precipitate. This precipitate is separated, washed and added to a thousand parts of water, by which it is dissolved. The 50 parts of cyanide of potassium are then added to the solution, thus forming the double cyanide required for the bath.

The bath for nickel-plating generally consists of a double sulphate of nickel and ammonium, from five to eight parts of the salt being dissolved in 100 parts of water. According to the usage of some practical electro-platers sulphate of ammonium and citric acid are added to this solution.

When it is desired to obtain a thicker coating or plating at some parts of the article than at others, a method of plating called sectional-plating is adopted. Sectional-plating is especially applicable to such objects as spoons, etc., which are thus given a greater thickness of deposit at the under parts of the bowl and handle, where the spoon for the greater part rests, and is thereby exposed to greater wear.

In order to prevent too thick a coating of silver or other precious metal from being deposited on the articles in the bath, thus increasing the cost, an automatic device called a plating balance is frequently employed, by means of which the plating circuit is automatically broken as soon as a certain increase in weight has been reached. This is accomplished by suspending the objects to be plated at one end of a balance so that, when a certain increase in their weight has been gained, the balance tips, and breaks the circuit.

When articles are to be replated, the old plating

is removed, both for purposes of economy and in order to readily obtain the chemically clean surfaces required. This is accomplished by what is called a stripping bath, and is effected either by simply dipping the articles in an acid bath, or by electric action.

The character of the deposit produced by electro-metallurgy depends not only on the density of the current employed, and on the strength of the solution, but also on the size and position of the anode as compared with the size of the objects to be plated.

There are two well-known kinds of deposits, namely:

(1.) Reguline, or flexible, adherent and strongly coherent, metallic films. These deposits occur when neither the current nor the solution is too strong.

(2.) Crystalline, or non-adherent, and non-coherent deposits.

The crystalline deposits may be either of a loose, sandy character, which occur when the deposit is produced by a feeble current with too strong a solution, or they may be black deposits, which are thrown down when too strong a current is employed as compared with the strength of the solution.

Electro-typing is that branch of electro-metallurgy

by means of which copies, reproductions, or duplicates of various objects are obtained in metal by means of electricity.

The process of electro-typing effects in general what was previously obtained only by pouring the fused metals into molds suitably prepared to receive it. The process of electro-typing is, therefore, sometimes called the cold casting or molding of metals. The process of electro-typing was originally called the galvanoplastic process, but is now generally called the electro-typing process.

In the electro-typing process, the surface of the articles which are to be reproduced, if not already electrically conducting, is rendered so by any suitable process. This is readily effected by means of finely divided black lead or plumbago that is dusted over the non-conducting surface and polished until it shines; or it may be effected by depositing various metallic substances over the surface of the article, by heat or by chemical action, or by painting metallic powders over such surfaces.

An electro-type can be readily taken of a coin by very slightly greasing its surface and then depositing a comparatively thin coating of copper over it. The deposit may then be cut at the edge of the coin by a penknife, when it can be readily removed, the

slight film of grease that covers the coin preventing it from adhering to the coating. Molds of various articles can be made with plaster of Paris, wax or glue, which, after hardening, are rendered electrically conducting.

The most important application of electro-typing is seen in the reproduction of copper, wood or steel engravings, or of type for printing. When properly carried out these reproductions present in detail the finest lines of the cuts from which they have been made. Such reproductions are called electrotypes, and are employed for printing from in place of the ordinary wood cuts or steel plates. In this manner any number of impressions can be taken without destroying the sharpness of the outlines of the original cuts.

In order to protect the surface of an electro-type from wear, when it is desired to make a very great number of impressions from it, the surface is sometimes covered by a layer of steel or very hard iron deposited by electro-plating. This process is generally employed in the case of electro-types made from steel plates.

In order to obtain the best results in electro-plating or electro-typing, the strength of the current produced by the source must remain constant.

Originally voltaic batteries only were employed for furnishing the electricity required The difficulty of maintaining the current of such batteries constant and the attention necessary to be given them during operation have led to the very general use of dynamo-electric machines. Here the maintaining of the machine at its proper speed ensures a constant current.

Numerous applications of electricity to the reduction of metals from their ores have been made, in which heat produced either by the voltaic arc, or electric incandescence, is employed to effect the reduction, or the electrolytic power of the current is employed for the same purpose.

The devices employed for such purposes are generally known as electric furnaces. In electric furnaces electrically generated heat is employed for the purpose of effecting difficult fusions for the extracting of metals from their ores, or for electro-metallurgical operations generally.

The heat is derived either from electric incandescence or from the voltaic arc. In the latter case the substance to be heated is exposed directly to the heat of the arc. In some forms of furnace the ground ore is permitted to fall directly through the arc, and the molten matter received in suitable ves-

sels, in which the separation of the metallic substances is afterward effected. In other forms of furnace the fused ore is placed directly between two electrodes formed of carbon or other refractory substance, and a powerful current passed through the mass.

In 1851 Charles Watt took out letters patent in England for a process for the electric separation of metals from their ores, in which an electric current was sent through a mass of ore that had first been fused by means of ordinary heat.

In 1873 Werdermann took out letters patent for a continuous process in which a fused mass of crushed and heated ore had a current of electricity sent through it for the purpose of effecting the reduction of the metal. The current was sent through the heated ore between electrodes of carbon or other suitable substance.

In 1879 Werner Siemens took out letters patent in England for an electric furnace, or crucible, in which the electric separation of metals from their ores was effected, or in which difficult fusions were obtained, by means of heat of electric origin.

For this purpose the heat of the voltaic arc was employed, the arc being formed between two carbon electrodes placed inside the crucible, which was

formed of some refractory material. Siemens' furnace, although produced mainly for the purpose of readily obtaining an intense heat, was also designed for effecting metallurgical operations.

In the Cowles furnace for the electrical reduction of aluminium, both the heat of the voltaic arc and the electrolytic power of the current are employed for the reduction of aluminium from its ores. The voltaic arc is formed between two carbon plates so as to pass through a fused mass of aluminium ore, the separation of the aluminium being effected both by the heat of the carbon and the electrolytic power of the current. The aluminium is at once alloyed with a mass of copper placed in the bottom of the furnace so as to form one of the electrodes.

Electricity has been successfully applied to the refining of metals. When certain precautions are taken, metals, which are thrown down electrolytically from their solutions, are obtained in a chemically pure condition.

In the electrical refining of copper, for example, the plate of impure copper, which is to be refined electrolytically, is used as the anode of a copper bath, and placed opposite a thin plate of copper, which forms the kathode. The gradual passage of the current dissolves the copper from the

plate at the anode, and deposits it in a chemically pure condition on the plate at the kathode. Similar processes are employed for the refining of other metals.

A process has been devised for the direct production of phosphorus by means of electricity. The crude material, consisting of a mixture of bones and carbon, is fed into the space between two electrodes connected to the poles of a powerful source of alternating currents. The heat produced by the currents in the presence of the carbon decomposes the material, and the phosphorus, which is volatilized, is condensed in suitable chambers.

Various processes have been devised for the electrical protection of metallic surfaces from oxidation by the corrosive action of the air or water.

These processes are based on the fact that when chemical action occurs in any voltaic couple it is the positive plate only that is attacked, the negative plate being protected from any action as long as any portion of the positive plate remains. The method has been adopted with considerable success for the following purposes:

(1.) To protect the copper sheathing of ships from corrosion by sea-water, by attaching pieces of zinc to the sheathing. This plan, proposed by Davy,

succeeded so well that it had to be abandoned, since the copper solutions, which were formerly produced and acted as a poison to the marine plants and animals, being then absent, permitted these organisms to thrive to such an extent as seriously to foul the ship's bottom.

(2.) A ring of zinc attached to a lightning rod near its point protects the point from corrosion.

(3.) Iron bars for railings, when imbedded or sunk in zinc, are prevented from corrosion near the junction of the two metals; but if sunk in lead are readily corroded, because iron is electro-positive to lead, and the positive metal is always the one that is corroded.

(4.) Sheet iron covered with zinc, or, as it is generally called, galvanized iron, is protected from corrosion not only because zinc is positive to iron, but also by reason of a coating of insoluble zinc oxide which is formed. On the contrary, tinned iron rusts or corrodes rapidly wherever the iron is exposed to the atmosphere by abrasion or cutting, because iron is electro-positive to tin. For the same reason nickeled iron rusts rapidly on the exposure of abraded surfaces.

Bonney, in a book entitled "The Electro-Platers' Handbook,"* in speaking of the character of the electro-metallurgical deposit, says on page 131:

"Electro-deposited silver is pure, if the silver employed in making up the solution is pure and the anodes are also pure. As the articles leave the solution coated with silver their surfaces appear to have been whitewashed. The coat of pure silver upon them is composed of a number of fine grains beautifully massed and interlaced together. In this condition they absorb the light, and have a peculiar dead white appearance, named "matt" in the plating trade. If the solution is contaminated with copper or other base metal, or if the current is too dense, or if the solution is deficient in silver, or if the E. M. F. of the current is too high, the deposit will have a hard and dark appearance, and will be intractable to the burnisher. If the current is too dense the silver will go on loosely in dark gray grains, and the deposit is said to be burnt. This may be prevented by interposing a resistance in the circuit, and thus checking the volume of current passing through the article being plated. It may also be prevented by moving the article at a greater distance from the anode, or by placing more articles in the vat, or by lessening the anode surface exposed to the solution. If the E. M. F. of the current is too high, the bad effects just noted will be intensified, providing the volume is also large; but a thin

* "The Electro-Platers' Hand Book: A Practical Manual for Amateurs and Young Students in Electricity," by G. E. Bonnoy. London: Whittaker & Co. 1891. 208 pages, 61 illustrations. Price, $1.20.

current with a high E. M. F. will also deposit silver in a hard dark condition, different from that above noted. For this there is no other remedy except that of reducing the E. M. F. by driving the dynamo at a slower speed, or taking off battery cells and reducing the number in series. If the hard, dark appearance of the deposit is due to a deficiency of silver in the solution it must be remedied by adding more silver cyanide, or working with a weaker current and placing the articles nearer the anode. In another section (¶ 104) I give directions for analyzing a plating solution. If the solution is contaminated with copper or other base metal, it is only fit for the most common work, and can only be remedied by turning it over to the refiner to be evaporated and reduced to old silver, One other cause of dark silver must be mentioned here. This is due to the addition of brightening liquid to the solution, to get a bright deposit from it. A solution thus treated is spoiled for general work, and will rarely recover its former condition."

X.—STORAGE OR SECONDARY BATTERIES.

When an electric current is sent through an electrolyte, a tendency exists to set up an electromotive force that is oppositely directed to that of the electric source producing it.

This electromotive force is called the counter-electromotive force, or the electromotive force of polarization.

When an electric current is sent through the electrolyte in a plating bath, the collection of the ions on the two electrodes produces a polarization of the bath, which sets up a counter-electromotive force. This counter-electromotive force tends to produce a current in the opposite direction to that of the current by which it is produced.

In the case of some electrolytic cells, when the electrolyzing current ceases to pass, the cell becomes a practical source of electricity, and, when its terminals are connected by means of a conductor, produces a current which flows in the opposite direction to that of the electrolyzing current. Such a cell is called a storage or secondary cell. A number of

such cells, connected so as to form a single electrical source, is called a storage or secondary battery.

The student should carefully avoid the error of supposing that a storage battery or cell actually stores electricity.

It does not store electricity any more than the spring of a clock stores time or sound. What the spring stores is mechanical energy. It renders muscular kinetic energy potential; and this potential energy, by becoming kinetic, causes the works of the clock to move or strike.

In the same way the so-called storage battery stores the energy of the electric current by producing electrolytic decompositions of such a character as independently to produce a current when the electrolyzing current ceases to pass.

It may be well to consider here the source of the energy in a primary or voltaic cell and in the storage battery respectively.

In a voltaic cell the energy, which maintains the flow of electric current, is the chemical potential energy of the metal of the positive plate. The source from which the zinc plate obtained this energy was the heat of the smelting furnace, in which the zinc was reduced from its ores.

But the energy which maintains the flow of elec-

tric current in a secondary or storage battery is the chemical potential energy of a substance, generally metallic, deposited on one of the plates. The source from which it obtained this energy was the electric energy of the charging current. In point of fact, a storage battery, while being charged, forms an electric apparatus for the electrical reduction and superoxidation of a metallic salt in an electrolyzable solution. When the charging current ceases to pass, a storage battery becomes in point of fact an ordinary primary or voltaic cell. When such a battery or cell becomes exhausted, it can again receive energy from an electric current sent through it, and can thus again become active.

When two plates or electrodes of platinum are immersed in a solution of sulphuric acid, and an electric current is sent between them through such solution, the oxygen and hydrogen, which are liberated, collect on, and are absorbed or occluded by, the platinum electrodes, and produce a counter-electromotive force, which renders such cell capable of yielding an electric current in the opposite direction to that of the charging current, for some time after the electrolyzing current has ceased to pass.

In other words, the electrolytic cell becomes a secondary or storage cell. In point of fact the first

storage cell was a cell of this character, and was produced by Ritter, of Germany. A storage battery of this general character is shown in Fig. 66 in the form of what is generally known as the gas battery.

A gas battery consists of electrodes or plates of platinum or other solid substance that possesses the power of occluding oxygen and hydrogen. These plates are dipped at their lower portions in dilute sulphuric acid and have their upper portions sur-

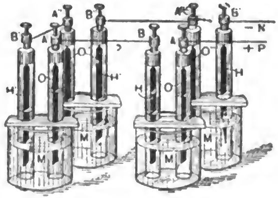

FIG. 66.—GAS BATTERY.

rounded respectively by the oxygen and hydrogen that have been liberated by the electrolytic decomposition of the sulphuric acid.

When a charging current is sent through the sulphuric acid between the platinum or other electrodes, the gases that are liberated collect in the upper parts of the apparatus, where they are occluded or absorbed by the platinum plates. They are

also occluded by the portions of the plates below the surface of the acid.

When, now, the charging current is discontinued, a current is produced by the battery, which passes through the electrolyte of dilute sulphuric acid in the opposite direction to that of the charging current.

By the capacity of a secondary or storage cell is meant the product of the current in ampères by the number of hours during which the battery, when fully charged, is capable of furnishing a current until exhausted. The capacity of a storage cell is given in ampère-hours.

The capacity of a storage cell or battery formed of platinum electrodes is quite small, and such a battery is therefore uncommercial.

A storage battery with a capacity of 1,000 ampère-hours can furnish, say, a current of 50 ampères for 20 hours, or a current of 100 ampères for 10 hours, or a current of 25 ampères for 40 hours.

When an electric current is passed through the electrolyte of a storage cell, the liquid is decomposed, and its electro-positive and electro-negative radicals or ions are either deposited on the surface of the plates or unite with them. The electro-positive rad-

icals or kathions are liberated at the plate connected with the negative terminal of the source, and the electro-negative radicals or anions are liberated at the plate connected with the positive terminal of the source.

The positive plate of a storage battery is the plate which is connected with the positive terminal of the charging source, and, therefore, receives the electro-negative ions or radicals. This usage has arisen from the fact that this plate of the storage battery becomes the positive pole of the battery on discharging.

The positive plate of a storage battery employing lead, therefore, is that plate which is partially or completely converted into lead peroxide by the action of the charging current.

The negative plate of a storage battery is the plate which is connected to the negative terminal of the charging source, and which, therefore, becomes the negative pole of the battery on discharging.

By the action of the charging current the negative plate becomes partially converted into spongy lead.

On the cessation of the charging current and the connection of the charged plates of a storage battery by a conductor outside the liquid, a current is pro-

duced which flows through the liquid from the plate partially converted into electro-positive radicals to that partially converted into electro-negative radicals; or the current produced on discharging flows in the opposite direction to that on charging.

In 1859 Gaston Planté found by replacing the platinum electrodes by sheets of lead, and employing the same electrolyte, namely, dilute sulphuric acid, that the capacity of the storage cell so formed was very greatly increased.

The Planté storage battery, as originally constructed, is subjected to a process called the "forming process." In this process the electric current is sent between the two plates through the dilute sulphuric acid, first in one direction, and then, when a certain charge is imparted, in the opposite direction, and the process repeated each time in an opposite direction. The effect of the charging current is to coat one of the plates with lead peroxide. If, now, the direction of the current is reversed, the other plate is covered with lead peroxide, and the lead peroxide deposited on the plate by the former current is converted into spongy lead. When the plates are fully charged by sending the current through the dilute sulphuric acid in alternately opposite directions, much of the surface of one of

the plates is converted into lead peroxide, and of the other into spongy, metallic lead.

By means of this charging and reversing process the amount of the peroxide on the positive plate is greatly increased, so that the capacity of the storage battery or cell is much greater than it would have been had a single charging current been sent through the electrolyte.

Let us consider the actions which take place during the charging and discharging of an ordinary

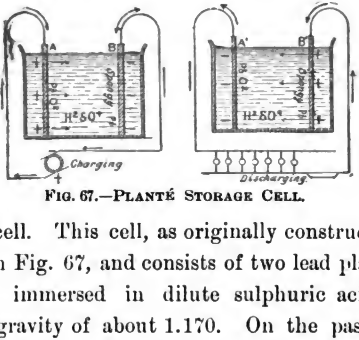

FIG. 67.—PLANTÉ STORAGE CELL.

Planté cell. This cell, as originally constructed, is shown in Fig. 67, and consists of two lead plates, *A* and *B*, immersed in dilute sulphuric acid of a specific gravity of about 1.170. On the passage of the charging current the active material on the positive and negative plates is converted respectively into lead peroxide, Pb O_2, and finely divided, spongy lead. The peroxide is formed on the positive plate and the spongy lead on the negative plate.

When the cell is fully charged, the acid solution loses its clearness, and becomes milky white in appearance and increases in specific gravity. This increase in specific gravity is a sign that it is charged.

When the charging current ceases to pass, the cell discharges in the opposite direction, that is, from B' to A', or from the spongy lead to the lead peroxide through the electrolyte.

As a final result of this discharge the lead peroxide $Pb\,O_2$ on A', gives up one of its atoms of oxygen to the spongy lead on B', thus leaving both plates coated with a layer of $Pb\,O$, lead monoxide, or litharge. When this change is thoroughly effected the cell becomes exhausted, and will furnish no further current until it is again charged by the passage of a current from some external source.

It will be noticed that during charging, oxygen is transferred from the $Pb\,O$ on one plate to the $Pb\,O$ on the other plate, thus leaving on one plate spongy or metallic lead, Pb, and on the other plate peroxide, $Pb\,O_2$. On discharging, one atom of oxygen is transferred from the $Pb\,O_2$ on one plate to the Pb on the other plate, thus leaving both plates covered with $Pb\,O$.

In reality this is but the final result of the action, hydrated sulphate of lead, $Pb\,O\;H_2\,SO_4$, being

formed and subsequently decomposed. Other compounds are also formed that are but imperfectly understood.

The action is probably as follows, namely: When the battery is charged the oxygen decomposes the sulphate on the positive plate, the result of the previous discharge, and converts it into peroxide of lead, liberating sulphuric acid ; while the hydrogen decomposes the sulphate of lead on the negative plate, resulting from the previous discharge, reducing it to spongy lead and liberating the sulphuric acid.

In order to decrease the time required for forming secondary batteries, metallic plates are sometimes covered with litharge, $Pb\ O$, and red lead, $Pb_2\ O_3$, to avoid forming the lead plate in the ordinary Planté cell. These plates are dipped into dilute sulphuric acid as before, and on the passage of the charging current the red lead is converted into lead peroxide at the anode, and the litharge into metallic lead at the kathode. Plates of compressed peroxide have also been recently used for this purpose. Such storage cells have a greater storage capacity per unit of weight than those in which a grid is employed, but they also have a higher resistance.

Where, in order to increase the capacity of the

storage battery, lead peroxide or red lead is spread over the surface of the plate, it is apt to become detached therefrom, and thus injure the working of the cell. It has been found advisable in practice to place the material in the shape of plugs in holes that are formed in the lead plate. These holes are generally shaped so that when the plugs once harden they cannot fall out.

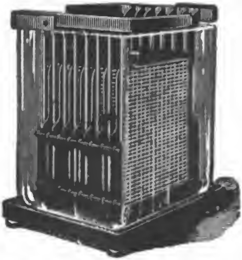

FIG. 68.—STORAGE BATTERY.

The lead plates, which receive the different deposits, are termed grids, and are formed with various irregularities of surface, so as to increase the extent of the surfaces of the plates.

In operation, unless care is exercised in charging, the plates become buckled or distorted in shape, by reason of the difference of expansion between the lead and the plugs of oxide. Buckling not only tends

to disintegrate and break up the plates, but also short circuits the cell by making contact with the negative plate.

FIG. 69.—STORAGE CELL OF CONSOLIDATED ELECTRIC CAR.

A common form given to the storage battery is shown in Fig. 68.

The well known type of storage cell shown in Fig. 69 is that of the Consolidated Electric Storage Co. This cell, which occupies a floor space of 12 by 12 inches, and has a height of 13½ inches, has a capacity of 350 ampère hours at one-half an ampère per plate.

During the working of a storage battery considerable difficulty is often experienced from what is called sulphating. Sulphating arises from the abnormal formation of sulphate of lead on the surface of the plate. The addition of a small quantity of soda will, it is claimed prevent this difficulty to some extent.

In the construction of the storage battery all joints in the lead plates should be burned or melted together. They should not be soldered, since the local action that would occur at the junction so formed would soon ruin the battery.

The electromotive force furnished by a single storage cell with a lead grid is a trifle over two volts. The electromotive force of the charging source, which is generally a dynamo electric machine, should be about 2.3 to 2.5 volts for each cell that is placed in series during charging. For example, if 10 cells be charged in series, the electromotive force of the charging dynamo, at the normal rate of charging, for the type of cell should be from 23 to 25 volts.

Besides the storage batteries of the Planté type, or modifications thereof, in which plates of lead similarly prepared are used in a solution of sulphuric acid in water, there have been devised a great variety of forms. The following will suffice as examples, namely:

(1.) The lead sulphate of zinc cell, in which two lead plates are immersed in a solution of zinc sulphate. On the passage of the charging current one plate becomes coated with lead peroxide and the other with pure zinc.

(2.) The lead sulphate of copper cell, in which two lead plates are immersed in a solution of copper sulphate. On the passage of the charging current one of the plates is coated with lead peroxide and the other with metallic copper.

The electromotive force of the lead sulphate of zinc couples is, according to Reynier, as high as from 2.8 to 2.6 volts, but soon falls to from 2.3 to 2 volts.

The best results are obtained from storage batteries when the rapidity of the discharge is not very great. If they are discharged too rapidly the battery soon deteriorates. With a slow discharge, an efficiency, rated in ampère-hours, as high as 95 per cent. can be obtained. By a rapid discharge this efficiency may be decreased as much as one-half.

It has been found preferable in practice to stop the discharge before the battery is entirely discharged.

Storage batteries are especially adapted to the purpose of supplying currents for light and power, during times when it is not desirable to run the charging dynamo. For example, in situations where electric light or power is required at night, under circumstances when the power is shut off. In such cases, storage batteries may be charged during the daytime, when the engine is in operation, so that at night, when the engine stops, light and power can be furnished by the battery.

Perhaps the most promising field to be found for the future of the storage battery is in that of electric traction. Storage batteries may be placed on passenger cars in systems of city railways, and their currents employed to drive a motor placed on the car truck. Such storage batteries work very satisfactorily where the grades on the line are not too great. When such grades are large, in order to obtain the power necessary to run a loaded car up a steep gradient, the battery requires to be discharged so rapidly that it either rapidly deteriorates, or supplies the current at a very greatly diminished efficiency.

Storage batteries, however, are being rapidly improved, and it may be reasonably expected that this difficulty will soon be eventually entirely overcome.

EXTRACTS FROM STANDARD WORKS.

In his work on the voltaic cell (page 320*) Park Benjamin, in speaking of gas batteries, explains how these, in reality, form a variety of secondary or storage cells :

"Grove Cell (1829).—Hydrogenated platinum, oxygenated platinum. The platinum electrodes are immersed at their lower ends in dilute sulphuric acid. Any voltameter containing water acidulated with sulphuric acid and platinum plates may serve as a gas cell. Grove's cell may work as a primary cell if the tubes of the voltameter be filled one with oxygen the other with hydrogen prepared by ordinary chemical processes. According to Matteucci, the action of the platinum wires may be increased by warming them for a few moments in the flame of an alcohol lamp before using them as electrodes. Under the most favorable condition the E. M. F. of the gas cell containing wires of non-platinized platinum scarcely exceeds 0.843 volt. The E. M. F. of the Grove element is independent of gas pressure ; but its intensity (strength) is perceptibly proportional thereto.

"Grove considered the seat of chemical action to be at the line of contact of the platinum, liquid and gas. This

*"The Voltaic Cell: Its Construction and Its Capacity," by Park Benjamin, LL. B., Ph. D. New York: John Wiley & Sons. 1893. 562 pages, 200 illustrations. Price, $5.00.

appears inconsistent with the fact that a continuous current is obtained with water holding hydrogen in solution in one tube and oxygen in another. De la Rive (1843) and Gaugin (1867) thought the development of electricity in the Grove cell to be due to the chemical action exercised on the hydrogen, under the influence of the platinum, by the dissolved and not by the gaseous oxygen. According to H. F. Morley (1878), at least a part of the current from the gas cell is due to dissolved gas. Magunna (1886) concludes that the hydrogen which adheres to the platinum combines with the oxygen of the water, the hydrogen of which last forms an equal quantity with the oxygen surrounding the other platinum plate. There would be, therefore, at the positive electrode, decomposition and recomposition of a like amount of water ; at the negative electrode, combination of the hydrogen of the water with the oxygen in the containing tube. Although the two gases may combine through the medium of the water, the conditions are as if the hydrogen contained in one tube combined directly with the oxygen contained in the other tube.

"Glucher Gas Cell.—This is constructed on the same principle as the Grove cell, with a special arrangement adapting it for practical use.

"Smith Gas Cell —A Grove gas cell so arranged as to accumulate gas under a pressure of six or seven atmospheres, and to store it up in sufficient quantities so that the apparatus may act as an electrical reservoir.

"A. S. Herschel Gas Cell (1882).—Platinum plates heated for several days at a high temperature in a crucible filled with lampblack. The surface of the plates has a

rough carbon deposit. The cell is formed in the same way as the preceding."

Salomons, in a work entitled "Electric Light Installation,"* on page 48, speaks thus of charging a storage battery:

"The first charge differs, in some respects, from charging in the general way. There should be a steady run of thirty hours without stoppage, if possible; or not less than ten hours a day during three successive days, for the size of cells commonly in use. The electrolyte will then commence to boil; it will have a milky appearance, due to the quantity of gas bubbling through the fluid, and its specific gravity will rise to about 1.200 by the acidometer. The word "boil" is meant to indicate not a rise in temperature, but simply the appearance of a liquid in that state. The charge must be continued until every cell boils in an equal degree. The current should be kept well within the permitted maximum. For some weeks, probably, there will be a difficulty of getting the cells into an equal state; and long charging alone will secure this. Overcharging does no harm whatever unless the current is too great. If one particular cell, here or there, will not boil, it is best disconnected from the circuit during hours of discharge; but it must be re-established when charging is started. Should this fail to attain the desired result the plates must be examined. Every cell should be separately tested for E. M. F., which

* "Electric Light Installation and the Management of Accumulators, A Practical Handbook," by Sir David Salomons. Sixth edition. London: Whittaker & Co. 412 pages, 106 illustrations. Price $2.00.

should not be less than 2 volts; if under 1.9 volts, the cell has been discharged as low as is consistent with safety. When nearly charged, 2.1 to 2.2 volts per cell will be registered. At the conclusion of a charge, each cell for a short period of ten or fifteen minutes gives as much as 2.3 to 2.5 volts. Then the E. M. F. drops to near the normal, and, after a slight discharge, the usual E. M. F. will average 2 volts per cell as nearly as possible. These tests are taken on open circuit; that is, when the cells are neither charging nor discharging."

Preece and Maier, in their book on the Telephone,* in speaking of telephone exchanges, say on page 232:

"The working of central stations differs according to country and locality, but as regards essential features differs only according to whether one or the other of the two leading principles is adopted.

"According to one method, the subscriber who wishes to enter into conversation with another subscriber first calls the central station; upon receiving an answer from the latter, the caller informs the operator at the exchange of the number of the desired correspondent, who is, in his turn, called by the operator. As soon as an answer has been received to the latter call connection is made between the branch lines.

"According to the second method, the calling subscriber

* "The Telephone," by William Henry Preece and Julius Maier. London: Whittaker & Co. 1889. 498 pages, 290 illustrations. Price $4.00.

likewise designates the desired correspondent, and, if the latter is disengaged, connection is forthwith made at the exchange between the two branch lines, and both the call and the further communication are left to the calling subscriber.

"In both cases the caller has to inform the central station of the end of the conversation by means of some prescribed form of clearing-out signal.

"As soon as this has been done, the branch lines are again disconnected and return to their normal condition.

"The former method was generally used at the earliest exchanges, and it is still to be found in many central stations; it presents the advantage that at the exchange the same signal may be used both for the call and for the end of the conversation, without fear of mistaking either of the signals. On the other hand, this system requires a larger staff of employés, and the working expenses are proportionately higher. The advantages and drawbacks of the second method of working will be clearly discernible from these remarks and the choice between the two will depend upon the consideration whether safety of working or economy has paramount claims.

"The earliest telephone exchanges had, besides the apparatus which announced the fact of a subscriber having called, and of which each branch line possessed one, a number of special 'clearing-out relays' or apparatus for announcing the end of a conversation. The number of these apparatus may be limited where telephonic messages are not very numerous; but, on the other hand, where a lively telephonic intercommunication takes place the num-

ber is considerably increased. It is, therefore, of great importance to devise a means for obtaining security in distinguishing the calling and clearing-out signal, employing one and the same apparatus for the same purpose."

XI.—ELECTRICITY IN WARFARE—ELECTRIC WELDING.

Electricity plays an important part in the art of war as well as in the peaceful arts.

Electricity is employed for many different purposes both at sea, on the man-of-war, and on the shore, in the fortress and the fortification.

The modern warship carries an extensive electric plant; for, electricity forms an indispensable part of its equipment. A man-of-war requires current for electric lighting, both for general purposes and for maintaining its powerful search lights; it requires current also for the driving of numerous electric motors, which now replace the small engines formerly employed for hoisting, pumping and other similar purposes; for the charging of storage batteries; for the propelling of electric launches, torpedoes, boats, and for a great variety of other purposes.

Electric plants are also established on land for the production of electricity for similar purposes. In addition to the above, various systems of telegraphy and telephony are maintained and are extensively employed in land manœuvres. Apparatus

called range finders are used to give to the gunner a ready means for finding the exact range for his guns. Various devices are employed for igniting or exploding subterranean or submarine mines; for propelling and exploding torpedoes; for accurately measuring the velocity of projectiles, so as to thereby test the explosive power of gunpowder or other explosives, and for a great variety of other purposes.

Apart from an increased speed of the vessels, perhaps the greatest advances in modern naval warfare have been made in the direction of armor to protect the vessels against destruction by projectiles, and in improvements in projectiles, whereby almost the heaviest armor can be destroyed.

The improvement in projectiles, both as regards size and velocity, has reached such a point that it would seem that the improvement in protective covering had almost reached its limit, especially since guns have been designed for the projection of dynamite cartridges. Then, too, apart from any protective covering which it is possible to give the vessel, the improvement in various forms and systems of torpedoes are such as to render it a comparatively easy matter to destroy the strongest and stanchest ship that it is possible to produce.

To decrease the liability of sinking the modern

warship by means of local damage to any part of its hull, the ship is provided with a series of water-tight compartments.

Probably one of the most important parts which electricity plays in the modern warship is the ready means it affords for the protection of the ship against the approach of enemies' vessels, or against dangerous torpedoes, by the powerful illumination obtained by means of the electric search light, with which every modern warship is now provided.

An electric search light consists essentially of a powerful voltaic arc, that is so maintained at the focus of a parabolic or other reflector as to throw an approximately parallel beam of light in any desired direction. In order to maintain the arc at the focus of the parabolic reflector, some form of focusing electric lamp must be employed, in which both carbons are fed, the positive carbon, of course, being fed more rapidly than the negative.

An excellent form of search light, known as the Mangin projector, consists of a concavo-convex glass, the convex surface of which, being silvered, acts as a concave reflector. The radius of curvature of the two surfaces of the glass is of such a value that the light enters and passes out of the mirror in a condition of practically absolute parallelism.

The Mangin projector is shown in longitudinal section and cross section in Fig. 70.

The reflector *B*, is placed at one end of the cylinder *A*, furnished with suitable openings for ventilation. The cylinder is supported on trunions, so that by means of screws it can readily be given any desired inclination.

The source of light is an arc lamp of the focusing type. A small disc is placed in front of the arc for

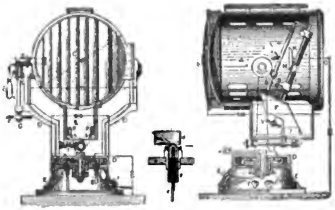

FIG. 70.—MANGIN PROJECTOR.

the purpose of stopping the direct light from the arc, which, of course, is formed of converging rays. The door *C*, of the chamber is formed of a number of cylindrical lenses placed parallel to one another so as to cause the rays to diverge horizontally when so desired.

In the Mangin projector the light is directed by means of an attendant to any part of the horizon that is to be illumined. In the automatic search

light means are provided whereby the beam of light is automatically caused to sweep the horizon and thus disclose the approach of a torpedo boat or other similar danger.

The search light is also available for purposes where ships unprovided with artificial illumination can safely enter a harbor only during certain tides, since when provided with search lights, ships, when so desired, can enter during the night as well as during the day.

In the electric range-finder, an invention of Lieut. Bradly A. Fiske, a device is provided by means of which the exact distance of an enemy's ship, or other object, can be readily determined, so that the gunner can make the proper allowance for range.

The operation of the range-finder is based on a method similar to the solving of a triangle for the purpose of determining distances. If the base line of a triangle and the two angles at the base are known, the other two sides and the included angle can be readily calculated.

In the range-finder the resistance of a German silver wire corresponds to the graduated arc of the theodolite used to measure the angles, and a rheostat, as a receiving instrument, measures the value

of the angles. The base line is a constant, so that the receiving instrument is marked in yards instead of degrees. To use the range-finder, two observers watch the target continuously through telescopes. They do this and nothing else, while a third observer watches a galvanometer and so alters the value of a resistance, by moving a contact or slide key along a resistance wire, as to keep the needle of the galvanometer constantly at zero. The exact distance being thus ascertained, the gunner can make the proper allowance for firing.

In the electric position-finder, also an invention of Lieutenant Fiske, means are provided by which the exact position of an object can be ascertained. so that a gunner can be telephoned, or otherwise ordered, to fire at objects he cannot see, and yet obtain a fair degree of accuracy.

In the electric ammunition-hoist, an electrically operated hoist is employed for raising ammunition to the deck of a ship.

The electric motor, which moves the hoist, is made to follow both in direction and speed the motion of the operator's hands. The motion of a crank, or wheel, causes a switch to start an electric motor in a certain direction, which tends to close the switch, thus necessitating a race between the

operator and the motor. Should the operator begin to close the switch more slowly, the motor will overtake him, and, by partially closing the switch, will thus lower the speed of the motor.

The man-of-war, as well as the merchant marine, is frequently provided with an apparatus for electrically measuring and recording the speed of the vessel. This device is called an electric log. It consists essentially of a wheel with vanes like a propeller, which register the number of its rotations by means of a step-by-step recording apparatus, operated by any given number of turns, say 100 or any other convenient multiple, by breaks in its circuit made during its rotation. Such a log may be kept constantly in the water, and observed when required ; or, it can be caused to make a permanent record of its actual speed at any time during the entire run of the vessel.

The enormous force developed by the explosion of gun-cotton, dynamite, or other explosive, is now extensively employed in warfare for the destruction of an enemy's ship or works by means of torpedoes.

Torpedoes consist essentially of water-tight compartments that are filled with some high explosive. This explosive is ignited either by means of a fulmi-

nate of mercury cap, which detonates a prime of dry gun-cotton, which in its turn detonates a full charge of damp cotton, or other substance placed within the torpedo, or is ignited by means of a suitable electric fuse.

Torpedoes are either stationary or movable. They may be divided into different classes, either according to the manner in which they are propelled, or moved through the water, or according to the manner in which they are exploded.

Stationary torpedoes are generally called submarine mines. They are either exploded by the shock of concussion on striking or being struck by the enemy's vessel, or by means of an electric discharge.

Movable torpedoes are either:

(1.) Drifting torpedoes, in which a number of torpedoes, suspended by a float and connected by means of ropes, are allowed to drift with the current so as to be brought into contact with the sides of the vessel. Such torpedoes are generally exploded by percussion; they may, however, be exploded electrically.

(2.) Towing torpedoes, in which a similar arrangement of floating torpedoes are towed after a vessel, and are exploded when they strike the side of the enemy's vessel. In such cases the torpedo is shaped

so as to maintain a safe distance during motion from the sides of the towing vessel.

(3.) Spar or outrigger torpedoes, in which the torpedo is attached to the end of a spar or outrigger, supported on the vessel, and exploded by percussion against the side of the enemy's vessel when thrust against the side below the water line. This form is very little used.

(4.) Automobile torpedoes, or those which contain in themselves the power of their own motion. These torpedoes are made in a great variety of forms. The moving power may be that derived from compressed air or gas, or from an electric motor driven by a storage battery contained within the torpedo, or by means of a current sent from the shore or from the vessel by a conducting wire or conductor. In the first case the torpedo is, of course, independent of the shore or the vessel; while in the second case it is necessarily connected with it by means of insulated wires.

There would thus arise two classes of automobile torpedoes; namely, the independent and the dependent.

In the Lay torpedo, the moving power is either carbonic acid, compressed air, or electricity. The torpedo has the form of a cylindrical boat with conical ends. The explosive is placed in the fore part of the torpedo. The torpedo is moved through

the water with its cylindrical body entirely submerged, its course being indicated by flags projecting above the surface. Electric mechanism is provided for starting, stopping, and steering the torpedo, the torpedo being connected with the ship or shore by means of an insulated cable.

In the Sims-Edison torpedo, electricity is both the propelling and directing power. The electric source is placed outside the torpedo, and an electric motor placed within; the torpedo is driven by means of the electric current transmitted through a cable connected with the sending station.

In the Halpine-Savage torpedo, as in the Sims-Edison, electricity is both the propelling and the steering power. In this form of torpedo, however, the source which furnishes the power is a storage battery placed inside the body of the torpedo.

Stationary torpedoes are generally called submarine mines. Such mines are sometimes placed underneath the earth, and are then called subterranean mines.

In a submarine mine a mass of gun-cotton or other explosive material is placed in a water-tight vessel under water, so as to be exploded from the shore on the passage of an enemy's vessel over it.

Submarine mines, or stationary torpedoes, are

generally designed for the protection of a harbor and are most conveniently placed at the entrance thereof. These mines are placed so as to be readily exploded from the shore on the passage of an enemy's vessel, but safely crossed by other vessels. The water-tight cases, in which the explosives are placed, are anchored in carefully located positions and connected to the shore by means of cables.

An operating room at the shore end of the cable is furnished with batteries, measuring instruments, contact keys, etc., by means of which the mine can be exploded by the transmission of an electric current through the cables. In ordinary times this current is too weak to ignite the fuse, and simply closes a relay in the operating room, which in turn directs a current through a bell or indicator, but is, of course, too weak to fire the fuse. In times of war, however, the relay sends a current through the cable sufficiently strong to ignite a platinum-iridium fuse and thus ignite a fulminate of mercury cap, which detonates a dry cotton primer and thus explodes the torpedo. Sometimes these mines are provided with automatic contact-closers, in which contacts are closed by the passage of the enemy's vessel over them, or by an operator placed at a safe distance within an entrenchment.

Various forms of fuses have been devised for igniting charges of torpedoes or mines; they may, however, be divided into two classes, namely:

(1.) High tension fuses, in which the charge is ignited by the direct action of an electric spark, and,

FIG. 71.—STRATHAM'S FUSE.

(2.) Low tension fuses, in which the ignition is obtained by means of heating a wire to incandescence by the passage through it of an electric current.

Stratham's electric fuse is shown in Fig. 71. It is a high tension fuse. The spark passes through a break *A B*, in the insulated lead *D*. Since gunpowder is not readily ignited by an electric spark, an especial priming material is placed in the break *A B*, instead of ordinary powder.

High tension fuses require a high electromotive force for firing. This is obtained either by the use of induction coils, electrostatic induction machines, or magneto-electric machines.

The general appearance of a form of magneto-

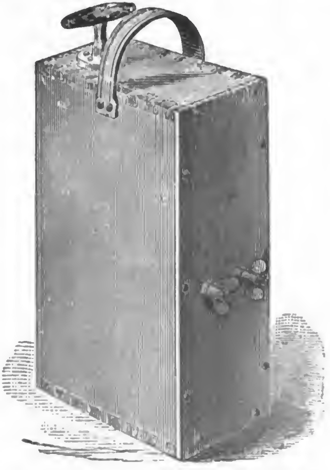

FIG. 72.—MAGNETO-BLASTING MACHINE.

electric blasting machine is seen in Fig. 72. The movement of the handle at the top of the machine causes a rapid rotation of a cylindrical armature. The current developed in the armature increases the strength of the field of the electro-magnets em-

ployed, and, when the proper strength has been obtained, the current generated is thrown into the outer circuit and ignites a fuse.

Various forms of electric launches or boats driven by electric motors, fed by storage batteries, have been devised. A form of electric launch constructed for the English government is shown in Fig. 73. It is 48½ ft. in length over all, by 8 ft. 9 in. beam, with an average draft of 2 ft. 2 in. It will carry forty fully equipped soldiers at a speed of eight knots per hour.

FIG. 73.—ELECTRIC LAUNCH.

Among the recent applications of heavy or powerful electric currents may be mentioned that of electric welding, which has been successfully carried into actual operation by Elihu Thomson.

In the process of electric welding the metals that are to be welded are heated to electric incandescence by currents obtained either from suitable dynamos or from transformers. They are then subsequently pressed or hammered into a good welded joint.

In order to successfully obtain a good welded joint, it is necessary that the surfaces be uniformly heated throughout, that they be kept free from dirt, and that the pressure required for their welding be readily regulated.

The ease with which surfaces can be electrically heated to any required temperature, while under the direct inspection of the operator, has rendered it possible not only to readily obtain such welded joints far more effectively than by the process heretofore in use, but also to greatly increase the number of metals that can be readily welded to one another.

In the process of Bernardos and Olzewski, a welding process is employed in which the necessary heating is obtained by means of a voltaic arc. Here the joints are practically fused together. The joints obtained from this process do not appear to be as efficient as those obtained by the Thomson process. This probably arises from the difficulty of keeping them as clean as in the Thomson process, because the voltaic arc burns the metal.

The Thomson apparatus for welding can be divided into two distinct classes, namely :

(1.) The direct system of welding.

(2.) The indirect system of welding.

In the direct system of welding, the apparatus for

which is shown in Fig. 74, the welding current is obtained directly from a dynamo connected with the welding apparatus.

The armature of this dynamo has two separate windings, one of fine wire, rendered continuous by a suitable commutation and employed to excite the field-magnet coils, and the other of very low resistance, formed of a U-shaped bar of copper and

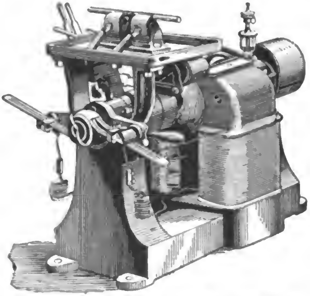

FIG. 74.—THE THOMSON DIRECT WELDER.

employed to furnish the welding current. No commutation is given to these currents, since alternating currents are equally adapted for furnishing the welding heat as are direct currents.

The terminals of the low resistance coils of the machine are connected directly to the clamps that hold the bar to the welder. These clamps are shown

in the top of the machine. One is fixed and the other is movable.

The principle on which this welder, and, indeed, all others of this character, operate, is the well known principle that a loose contact produces heat when an electric current is sent through it from the resistance it offers. The welding junctions, being made slightly convex, touch at but one point of their opposing faces, say near their centres. The welding heat is reached near their point of junction, and pressure is applied by means of a lever, screw, or hydraulic press, until all the welding surfaces are in contact. By this method the heat is obtained at the welding junction as required, as the joints are brought into contact under the influence of pressure.

The operation requires but a few seconds for small work, and, at the most, a few minutes for large work. The heating is practically local, extending in most cases to a distance of about the diameter of the weld.

Fig. 75 shows the apparatus for the Thomson indirect electric welding, the system in greatest use. This system is applicable to heavy work, or to cases where more than a single welding machine is to be operated by the current produced from a single dy-

namo. The indirect welder consists essentially of a suitably proportioned step-down transformer.

An alternating current dynamo, self or separately excited, is employed. The self-excited dynamo may be regulated by a reactive coil so as to give a varying electromotive force. The transformer is

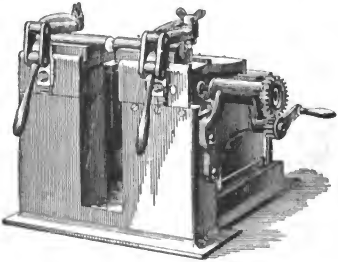

FIG. 75.—THE THOMSON INDIRECT WELDER.

constructed so as to give a different ratio of conversion by merely varying the relative position of the primary and secondary to each other, by shunting the lines of magnetic force by an iron bridge between the primary and the secondary, or by altering their number of turns by a switch.

EXTRACTS FROM STANDARD WORKS.

Concerning the many applications of electricity in warfare, Alglave and Boulard, in a work entitled "The Electric Light,"* on page 392, speak as follows :

"A short while after the Franco German war of 1870–71 gave the electric light a chance to make its *début* upon the field of battle under precisely those circumstances where its use was best understood--in a great siege.

"The defenders of Paris used it both as a source of light and as a means of telegraphic communication by optical signals. The lamps were those of Foucault and Serrin ; the source of electricity was Bunsen batteries, of not more than fifty elements, placed in the *poste d'octroi* all around the city. Upon one point, nevertheless, near Montmartre, an Alliance machine had been placed, which naturally furnished a much more energetic current and consequently a more intense light. The forts had also electric lamps, supplied from Bunsen batteries. But the reflectors which were used to direct the luminous beams were quite insufficient, and the lights themselves were not sufficiently powerful to light all expected localities.

"The electric light, nevertheless, rendered considerable service ; it prevented several nocturnal surprises, and re-

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* "The Electric Light: Its History, Production, and Applications," by Ém. Alglave and J. Boulard. Translated from the French by T. O'Conor Sloane, E. M., Ph. D. New York: D. Appleton & Co. 1884. 458 pages, 252 illustrations. Price, $5.00.

vealed several movements of the enemy which would, without it, have escaped notice. The Montmartre light, supplied by the magneto-electric machine, bathed with its rays the plateau of Argenteuil.

"The Germans used their electric light very skillfully to direct their battery practice and to keep track of our night operations. They had machines at their disposal, and hence obtained much more powerful lights than were given by our lamps supplied by Bunsen batteries.

"The dynamo-electric machine of M. Gramme, invented and presented to the Academy of Sciences at Paris in 1870, could only be known industrially after the Franco-German war. More powerful and much lighter than the Alliance machine, it was a source of electricity much better adapted to the necessities of war. Soon after the first Siemens machine appeared in Germany, which presented analogous advantages. The attention of military engineers was then again directed to the electric light. The Germans first studied it. At the Universal Exposition of Vienna, in 1873, they sent large projection apparatus, with an electric lamp, supplied by the first Siemens machine, designed by M. Heffner von Alteneck. In the French section a new electric projector was to be seen, specially destined for use at sea; but it belonged to the domain of individual industry. It was the work of MM. Sautter and Lemonnier, the great lighthouse builders of Paris.

"The Russian navy was the first to substitute the Gramme for the Alliance machines. In 1873 and 1874 the Peter the Great and Livadia tried the new apparatus, with lenticular projectors analogous to those of lighthouses.

XII.—SOME OTHER APPLICATIONS OF ELECTRICITY.

There are many other applications of electricity besides those already described or referred to in the preceding primers, and the number of such applications increases almost every day. There will be given in this primer a brief description of but some of the most important of these.

The ease with which electric power can be transmitted has led to its recent general use in mining operations, not only for the running of the cars for transporting ore, etc., but especially for the driving of various forms of electro-magnetic drills for tunneling and blasting purposes.

Electro-magnetic drills can be divided into two general classes; namely, rotary drills and percussion or reciprocating drills.

In the rotary drill, the drill is propelled by the rotation of the armature of an electric motor, the axis of which is connected to the drill either directly or by means of suitable gearing. In the percussion or reciprocating drill, the to-and-fro motions are given to the drill by means of electro-magnetism.

A very extended use has been made of electricity

in the various systems that have been devised for electrically igniting a stream of gas issuing from a gas burner. These systems are readily divided into two general classes; namely, those in which only a single gas jet is lighted at any one time, and those in which a number of separate gas jets are simultaneously lighted.

In any system of separate electric gas-lighting the issuing gas jet is ignited by an electric spark passed

FIG. 76.—SPARK COIL.

through it, thus avoiding the use of the dangerous friction match. In separate systems of electric gas lighting this spark is obtained by means of a spark coil; in multiple systems of gas-lighting it is obtained either by means of an induction coil or by some form of electrostatic induction machine.

A spark coil consists of a comparatively great length of insulated wire, connected to the circuit in which the gas jets to be lighted are placed. On the opening of the circuit of the spark coil, the extra spark so produced is utilized for the igniting of the gas.

The ordinary form of spark coil is shown in Fig. 76.

In any system of separate electric gas-lighting, although the separate gas jets are placed in separate circuits, yet a single spark coil and battery are employed for the entire system. Where the number of gas jets to be lighted by the multiple system is not very great a spark coil will give a spark of sufficient length. Generally, however, either an induction coil, or an electrostatic machine, is employed for such purposes.

In separate electric gas-lighting systems the opening of the circuit and the consequent production of the extra spark are obtained by means of a wipe-spark. This is generally accomplished by the pulling of a chain by means of which electric contacts are momentarily brought together and separated. The spark thus produced appears between the movable contacts, which are so placed that the spark passes through the issuing gas jet. In some forms of gas burners the gas is turned on by hand; in others it is both turned on and lighted by the motion of a pendant, and subsequently turned off by a motion of the same pendant, the first pulling of the pendant turning on the gas and lighting it, and the second motion turning it off.

Burners, operated on these principles, are made in various forms. The form shown in Fig. 77 is called the thumb-cock burner. Here the turning of the usual thumb-cock causes a platinum wire,

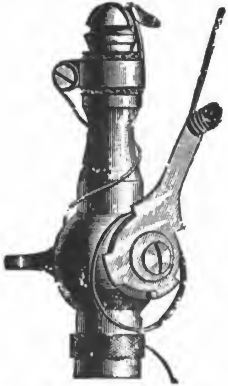

FIG. 77.—THUMB COCK BURNER.

which forms one part of the circuit, to come in contact with another platinum wire connected with another part of the circuit and placed near the jet of issuing gas. When the circuit is opened by this wire passing the contact, the extra spark on opening ignites the gas. A spark produced in this way by one contact sweeping over another is called a wiping or a wiper spark.

Another form of burner, in which the gas is first turned on and afterward ignited by means of a wipe-spark, is shown in Fig. 78. This form of burner is called the plain-pendant burner, because it is lighted by the pulling of the pendant chain, which moves the lever at *L*, into contact with another contact placed on the burner, as shown.

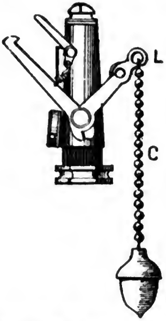

FIG. 78—PLAIN-PENDANT BURNER.

The above form is called the plain-pendant burner, in order to distinguish it from the ratchet-pendant burner, in which the first pulling of the pendant turns on and ignites the gas by means of an electric spark from the spark coil, and the next pulling of the pendant turns the gas off.

A ratchet wheel and pawl are operated by the motion of the pendant. The first pull of the pendant

chain moves the ratchet so as to open a four-way gas cock, and at the same time to light the gas at the burner by means of a wipe-spark from a spark coil. On the next pulling of the pendant the four-

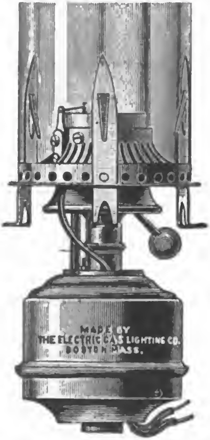

FIG. 79.--ARGAND ELECTRIC BURNER.

way cock is turned so as to turn off the gas. Alternate pulls, therefore, light and extinguish the gas.

Some forms of electric gas-light burners are both turned on and lighted and afterward turned off by the mere pushing of a push-button. Such burners are called automatic burners.

One push-button, usually a white one, turns the

gas on by energizing an electro-magnet, which operates the valves, and, at the same time, lights the gas by means of a succession of sparks from a spark coil. Another push-button, usually a black one, turns the gas off by energizing another electro-magnet. In order to insure the turning on or off of the gas, these motions are made positive motions.

The Argand electric burner, shown in Fig. 79, is a form of automatic burner. In some forms of automatic burners, the turning on or off of the gas is accomplished by means of a single push-button.

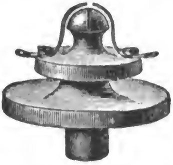

FIG. 80.—MULTIPLE GAS JET.

In multiple electric gas-lighting, a number of gas jets are simultaneously ignited by means of a discharge of sufficiently high electromotive force.

In multiple systems of gas-lighting the gas is turned on by hand, generally by the opening of a single cock, a series of sparks being then caused to pass simultaneously through each of the escaping gas jets.

The gas jet which is employed in multiple gas lighting apparatus is shown in Fig. 80. A spark is formed immediately over the slot in the burner and ignites the escaping gas by passing through it. Sparks obtained in this manner are sometimes called jump-sparks, in order to distinguish them from wipe-sparks.

The electric pen is a device for manifold copying, by means of which a sheet of paper is made into a stencil by minute perforations of a needle maintained in a rapid to-and-fro motion by a small electric motor.

This stencil is afterward placed on a sheet of paper and any required number of impressions are obtained from it by moving an inked roller over it. Mechanical pens, in which the needle is driven by clockwork or the motion of a treadle, have also been constructed on a similar plan.

Fig. 81 shows the arrangement of Edison's electric pen. The perforations are obtained by means of an electric motor driven by means of a small voltaic battery.

Electricity has been successfully applied for the purpose of engraving a metal plate by covering it with a thin layer of wax and tracing or cutting the design in the wax-covered surface, so as to expose

the surface of the metal. The metal plate so prepared is then connected with the positive terminal of a voltaic battery and placed in a plating bath opposite a plate of the metal.

By the action of electrolysis the metal is dissolved from the exposed portions and deposited on the plate connected with the other terminal of the battery. In this manner the design is obtained in the form of an etching or cutting on the plate. This process is known generally as electric engraving or

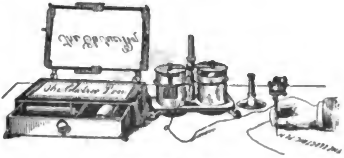

FIG. 81.—EDISON ELECTRIC PEN.

etching. By connecting the wax plate to the negative terminal of the source, and placing it as before in a bath, the metal will be deposited on the exposed portions, thus producing the design in relief. This latter method, however, is not apt to produce a sufficiently uniform deposit to enable the plate to be practically used for printing from.

Electricity has been applied to a device whereby a door may be automatically unlocked by the pressing

of a push-button. This device is called an electric lock. One form of electric lock is shown in Fig. 82. This lock is so arranged that the action of a push-button opens the door, provided, of course, the person in attendance in the house is ready to open or close the circuit. For this purpose a person wishing

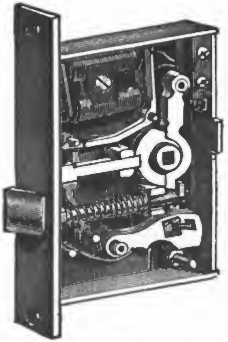

FIG. 82.—ELECTRIC LOCK.

to enter the house places himself in communication with an attendant by means of a speaking tube.

The use of electric locks is limited to apartment houses or public places, the janitor of which is constantly in attendance.

A commercial application of powerful currents, which has not yet been described, but which is

now coming into comparatively extended use, is the electric heater.

Electric heaters consist essentially of coils or circuits of some refractory material through which a sufficiently powerful current is passed to raise them to a high temperature. These coils or circuits, surrounded either by air, finely divided solids or enamel, are placed inside metallic boxes or radiators, whose extended surfaces readily throw off the heat imparted to them.

When employed for the heating of liquids the coils are either placed directly in the liquid to be heated, or the radiating boxes are themselves placed in the liquid.

It is a well known fact that an absorption of electric energy and a consequent decrease in temperature occur when an electric current flows across a thermo-electric junction in a certain direction. This reduction of temperature in the case of the antimony-bismuth couple can, when the current is passing from the bismuth to the antimony, be utilized for the production of small quantities of ice.

If, for example, plates of bismuth and antimony are placed as shown in Fig. 83, with a small cavity at *E*, between them and the terminals *C* and *D*, of a battery, or other source, be connected so as to cause

a current to flow across the junction from *B* to *A*, a few drops of water, previously cooled to the temperature of melting ice, is frozen by the lowering of temperature which occurs at the junction.

Very numerous applications of electicity are based on some of the many applications of electricity to electro-chemistry. Such processes insure the formation of new compounds either by electric combination, or by the breaking up of various compounds as in electrolysis.

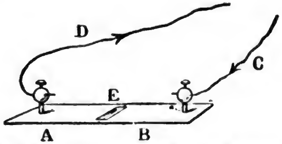

FIG. 83.—FREEZING OF WATER BY ELECTRICITY.

Among some of the most important of the electro-chemical applications of electricity are the following:

(1.) Electric tanning, in which electric currents are directly utilized for the purpose of tanning leather. The dressed hides are placed in a solution of tannin through which an electric current is passed. The tannin is placed in a vat furnished with suitable electrodes, and the articles to be tanned are placed between the electrodes, the liquid

being stirred by means of a motion given to the vat. By these means the time required for the completion of the tanning process is so much shortened, that it is claimed that hides are thoroughly tanned in from one to four days instead of from four to eight months, as required by the ordinary process.

(2.) Electric bleaching, in which electricity has been applied for the purpose of liberating bleaching agents by electrolytic action at the points where they are required for use.

In the process of Naudin and Bidet, the current from a dynamo is passed through sea water or through a solution of common salt placed between two closely approached electrodes The chlorine and sodium, so liberated, react on each other and form sodium hypochloride, which is drawn off by means of a tube and used for bleaching.

By other processes nascent hydrogen or oxygen are liberated, which are either utilized, when desired, to bleach articles placed between the electrodes, or are led off to suitable bleaching chambers. By still other processes electrolytically generated ozone is employed for bleaching purposes.

(3.) The electric ageing of alcoholic liquors or of wines, in which a rapid ageing of the liquid is ef-

fected by means of electrically produced ozone, instead of by the much less rapid process of ageing it by exposure in partially closed vessels to the action of the air.

(4.) The electric rectification of alcohol, by means of which the bad taste and odor of alcohol, which are due to the presence of aldehydes, are removed by the electrolytical conversion of such aldehydes into true alcohols by the addition of hydrogen atoms.

An electric current sent through the alcohol between zinc electrodes liberates hydrogen and oxygen by the decomposition of the water present in the alcohol. The nascent hydrogen then converts the aldehydes into alcohol and deprives the liquid of its fusel oil, while the oxygen merely forms insoluble zinc oxide.

A very curious application of electricity has recently been made by Hughes in an apparatus known as Hughes' induction balance, in which the presence of a conducting metal, or, in fact, any conducting substance, is so accurately indicated by the use of induced electric currents, that the difference in composition of two metals that are so nearly alike that it would be impossible to distinguish them by the eye is determined with great accuracy and certainty. The arrangement of the Hughes induction

balance is shown in Fig. 84. *A*, *C*, *D* and *B*, are bobbins wound with 300 feet of No. 32 copper wire. The coils are connected as shown at *A* and *B*, to the circuit of the battery, and *C* and *D*, to the circuit of a telephone. The coils *A* and *B*, are placed at a sufficient distance apart to prevent mutual induction taking place between them. The direction of

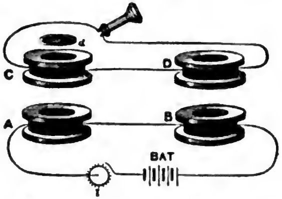

FIG. 84 —HUGHES' INDUCTION BALANCE.

winding the coils is such that the induction of *A*, on *C*, is opposite to that of *B*, on *D*.

Under these circumstances the coils *A* and *B*, act as primaries, and *C* and *D*, as the secondaries of an induction coil, the interrupter *I*, being placed in the circuit of *A* and *B*, for the purpose of continually making and breaking the circuit. The adjustment is such that the opposing secondaries produce practically no sounds to one listening at the telephone.

If, now, a single coin or mass of metal be introduced between *A* and *C*, or between *B* and *D*, or even

be brought near one of the coils, as at *d*, the balance is disturbed, since some of the induction is now expended in producing electric currents in the interposed metal, and a sound is consequently heard in the telephone. If, however, precisely similar metals are placed in similar positions between *A* and *C*, or between *B* and *D*, no sound is heard.

The slightest difference either in position or size destroys the balance and causes a sound to be heard in the telephone. By the use of Hughes' induction balance a spurious coin can readily be detected when compared with a genuine coin.

The electro-tasimeter is an apparatus invented by Edison to measure minute differences of temperature, or of moisture, by the resulting differences of pressure A change of temperature, or of moisture, is caused to produce variations in the electric resistance of a button of compressed lamp black, placed in the circuit of a delicate galvanometer. The electro-tasimeter, though of surprising delicacy, is incapable of practical application, because the resistance of the carbon does not resume its normal value on the removal of the pressure.

EXTRACTS FROM STANDARD WORKS.

In his "Dictionary of Electrical Words, Terms and Phrases,"* on page 431, the author gives the following description of Boys' radio-micrometer:

"The action of the radio-micrometer depends upon the deflection, by a magnetic field, of a suspended thermo-electric circuit composed of three metals, namely, two bars of antimony and bismuth, or of their alloys, which are soldered side by side to the end of a minute disc or strip of copper foil, as shown in Fig. 85. This disc or foil of copper is provided for the purpose of receiving the radiation that is to be measured. The upper ends of the thermo couple are soldered to the end of a long, narrow, inverted U-shaped piece of copper wire, which completes the thermo-electric circuit.

"The absorption of radiant energy by the copper disc connected to the thermo-electric couple produces an electric current, and the circuit, being suspended in a magnetic field, is at once deflected to a degree depending on the intensity of the radiation, or of the current generated at the thermo-electric junction.

"The means adopted for the suspension of the system are shown in Figs. 85 and 86. A small piece of straight wire is soldered to the upper end of the copper stirrup,

* "Dictionary of Electrical Words, Terms and Phrases," by Edwin J. Houston, A. M. New York: The W. J. Johnston Company, Ltd. 1892. 562 pages, 570 illustrations. Price, $5.00.

which completes the thermo-electric circuit. This wire is cemented to the lower end of a glass tube, the upper end of which is provided with a mirror, and the whole suspended, as shown, by a quartz fibre in the field of a powerful magnet.

"In a radio-micrometer made by Prof. Boys, the minute-

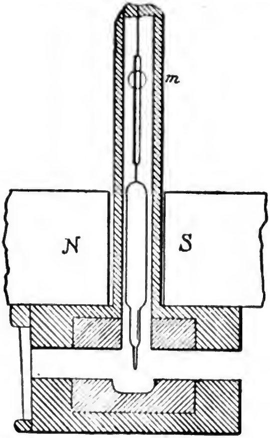

FIG. 85.—BOYS' RADIO-MICROMETER.

ness of the suspended circuit may be judged from the following actual dimensions, namely, thermo-electric bars $\frac{1}{8} \times \frac{1}{80} \times \frac{1}{200}$ inch; copper circuit of No. 36 copper wire, 1 inch long and about $\frac{1}{10}$ inch wide; copper heat-receiving surface, blackened on the face exposed to the radiation, $\frac{1}{10}$ inch in diameter, or $\frac{1}{4} \times \frac{1}{30}$ inch; receiver $\frac{1}{10}$ inch square,

$\frac{1}{300}$ inch thick; quartz fibre 4 inches long, $\frac{1}{5000}$ inch in diameter.

"This instrument, when properly adjusted for extreme sensitiveness, should give clear indications when the blackened surface is warmed but the $\frac{1}{2000000}$ degree centigrade.

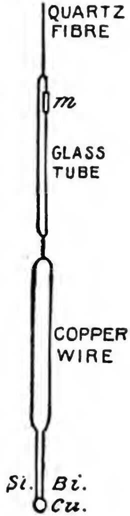

FIG. 86.—BOYS' RADIO-MICROMETER.

It will respond to the heat radiated on the surface of a halfpenny from a candle flame at a distance of 1,530 feet.

"In order to avoid the disturbance due to the magnetic qualities of the antimony and bismuth bars, the central

portions of the metallic block, inside which the system is suspended, is made of iron, as shown by the heavier shading in Fig. 85.

"This mass of iron serves as a magnetic screen to the thermo-electric bars, but permits action of the field on the circuit."

XIII.—ELECTRO-THERAPEUTICS.

There can be no doubt that electricity, intelligently applied to the human body, greatly aids in restoring it to a normal condition. The fact that electricity is invariably present in living organisms during their active life, as well as the marked effects which electricity produces when passed under certain conditions through the living animal, would apparently indicate that in electricity we have a potent agency for good or evil. In the hands of an intelligent practitioner, who is thoroughly acquainted with human physiology, and can distinguish between the normal and abnormal conditions of the organs of the body, electricity may accomplish much good, but in the hands of quacks, or the uninitiated, it may work irreparable evil.

Electro-biology is that branch of electric science which treats of the electric conditions of living animals and plants, and of the effects which electricity produces on them.

Electro-biology includes :

(1.) Electro-physiology.

(2.) Electro-therapeutics, or electro-therapy.

Electro-therapeutics is that branch of electro-biology which treats of the applications of electricity to the curing of diseased conditions of the human body.

Electricity is applied to the curing of disease in various ways, the most important of which are as follows :

(1.) By placing variously shaped electrodes on different parts of the body so as to cause the current to pass through the nerves or muscles either for the purpose of stimulating them to action, or of modifying their nutrition.

These electrodes are shaped either according to the character of the work they are intended to perform, or according to the parts of the body to which they are to be applied.

(2.) By means of needle-shaped electrodes, which are introduced into diseased growths, such as tumors, aneurisms, warts, cystic goitre, etc., for the purpose of treating the same directly by means of the electrolytic power of the current.

(3.) By utilizing the heating power of the current, as in the galvano-cautery, for the removal of diseased parts of the body by cutting or burning through them.

(4.) In the various determinations of electro-diagnosis, electro-prognosis, and electro-bioscopy.

There are three distinct characters of electric currents employed in electro-therapeutics, namely :

(1.) The galvanic current, or that obtained from the galvanic or voltaic cell.

(2.) The faradic current, or that obtained from induction coils.

(3.) Franklinic currents, or those obtained from frictional or electrostatic induction machines.

These currents are applied to the different parts of the body by means of conductors of various shapes, called electro-therapeutic electrodes, attached to the terminals of the source.

When the electricity is intended to affect the skin or superficial portions of the body only, the electrodes are applied dry, and are generally metallic. When the deeper structures, such as the muscles or nerves, are to be reached, metallic electrodes, covered by moistened sponges or absorbent cotton, are employed, the skin being thoroughly moistened before they are applied.

Such electrodes are rendered better conducting by being moistened by some saline solution, such as common salt.

When the electrodes of any source are placed at two different parts of the human body, the current does not pass directly between the electrodes along

the shortest path connecting them, but branches and flows through various paths, extending in a general direction between the electrodes. The current divides or branches according to the law of branched or derived circuits, and, therefore, flows in greater amount, or with greater current density, through the better conducting paths.

When, therefore, it is desired to obtain a greater density of current at some particular part of the body, the electrode, which is to be introduced into or placed over the part or organ to be treated, is made smaller than the other electrode.

When an electric current is sent through any particular part of the body, the general character of the effect produced will vary according to the manner in which the current enters and leaves the body at such part. In other words, this effect will vary not only with the character of the current, but also according to whether the anode or the kathode of the battery has been placed over the part to be treated.

In the majority of cases, in the normal condition of the nerves, it appears that the application of the kathode produces the greatest effect. In other words, when the electrodes are placed on different parts of the body, so as to send a current through these parts, the therapeutic effect is produced mainly in the neigh-

borhood of one of the electrodes only. This electrode is called the therapeutic electrode; while the other, which simply serves to determine the point of exit of the current, is called the indifferent electrode. Either the anode or the kathode may act as the therapeutic electrode, although, as already pointed out, the kathode so acts in, perhaps, the majority of cases.

Electrodes are made in a great variety of shapes. They are named either from the particular organs they are designed to treat, or according to the general character of the effects to be produced. For example, electrodes are distinguished as aural, vaginal, urethral, etc., from the organ they are designed to treat; or, as brush, disc, or point electrodes, from their shape; or, as clay, sponge, etc., from the material of which they are formed.

As regards the size of the electrodes the following standard sizes, as proposed by Erb, have been very generally adopted. The numbers and sizes are as follows:

(1.) Fine electrode, ½ centimetre diameter.

(2.) Small electrode, 2 centimetres diameter.

(3.) Medium electrode, 7.5 centimetres diameter.

(4.) Large electrode, 6 × 2 centimetres diameter.

(5.) Very large electrode, 8 × 16 centimetres diameter.

It is found advisable in electro-therapeutics to construct electrodes in such a manner as to avoid the effects of polarization. Non-polarizable electrodes have been obtained by the employment of two amalgamated zinc wires dipped in a saturated solution of zinc chloride, placed in glass tubes. The tubes are closed at the lower end by a piece of potter's clay, which serves as the portion of the electrode that is brought into contact with the body. Contact with the tissues of the body, by an electrode so prepared, does not produce any appreciable polarization.

The brush electrode takes its name from its shape. It consists essentially of an electrode furnished with fine wires that are inserted in a conducting plate like the bristles in a brush.

The disc-electrode, as its name indicates, consists of a disc-shaped electrode of various sizes.

The disc-electrode is either applied in a dry state, or is covered with absorbent cotton or some kind of cloth and applied moistened.

It is often desirable, during treatment, to change the polarity of the therapeutic electrode. This is accomplished by means of some pole-changing and interrupting device placed generally in the handle of the electrode.

When an electric current is sent through a nerve,

the effects produced will vary according to the character of the nerve. When sent through a motor nerve it causes a contraction of the muscles to which the nerve is distributed. When sent through a sensory nerve it causes pain. When sent through a mixed nerve—that is, a motor and a sensory nerve—it produces both pain and motion.

Muscles can be directly stimulated and so caused to contract, by the passage of electricity through them, as can be proved by the paralysis of the nerves by curare, a vegetable substance extracted from various members of the strychnos family, and known in South America as arrow poison.

In such cases, no increase of temperature is produced, save that which follows the contraction of the muscle.

It appears that the passing of a current through the body, generally results in some modification of its nutrition or assimilation, and, probably, this is one of the most important of the therapeutic effects of the current.

The stimulation of the muscles by the passage of electricity through them, or through the nerves when properly effected, should result in much good.

This would appear to be especially so in some cases of paralysis, where the muscles are gradually wast-

ing away from lack of exercise. In this case the motion given to the muscles by the action of the current might take the place of the motions that can no longer be given to the muscles through the action of the will.

So far as actual trial goes, it is found that electric stimulation of the muscles is beneficial in many such cases.

When the current of a voltaic battery is passed through a nerve a condition of altered functional activity is produced called electrotonus. This change or alteration may result either in an increase or a decrease in the functional activity as follows, namely :

(1.) The decreased activity occurs in the neighborhood of the anode or positive electrode, and is called the anelectrotonic state.

(2.) The increased functional activity occurs in the neighborhood of the kathode, or the negative electrode, and is called the kathelectrotonic state.

The altered activity not only affects the parts of the nerve lying between the electrodes, but also those which lie beyond them. Although the exact changes in the nature of the nerves that produce the change called electrotonus is unknown, yet such change is, probably, due to some electrolytic re-

arrangement of the nerve molecules, which alters their power of transmitting or carrying impulses.

According to Pflüger, a given tract of nerve is stimulated by the appearance of kathelectrotonus, and the disappearance of anelectrotonus, but not by the disappearance of kathelectrotonus, nor by the appearance of anelectrotonus. This fact is generally known in electro therapeutics as Pflüger's law.

The effect produced in a nerve, or in the muscles to which such nerve is distributed, is of a very different character when a galvanic current is employed than when a faradic current is employed.

When a galvanic current is employed, unless such current is of very great strength, the contraction of the muscle is only momentary. If the galvanic current is reversed, as by means of a commutator, these contractions are much stronger. Such reversals are known in electro-therapeutics under the general name of voltaic alternatives.

When a faradic current is employed, instead of a quick, momentary contraction, there is a prolonged contraction which lasts as long as the current is passing. The cause of this is probably to be ascribed to the rapidity with which the closings and openings follow one another; that is, in other words, the irritability of the nerve or muscle to the galvanic cur-

rent is greater than to the faradic current. Such irritability is generally distinguished as galvanic and faradic irritability. In the case of the contraction of a muscle produced by the galvanic current various phenomena are observed in the intensity of the contraction which follows the opening and closing of the circuit.

When the anode of a source is placed over a nerve, and a weak current is employed, the muscular contraction that is observed on the closing of the voltaic circuit is technically called the anodic-closure-contraction, and that produced on the opening of the circuit, the anodic-opening-contraction.

If the circuit is kept closed for a few minutes it is noticed that the contraction on opening is much greater than if it had been opened after keeping it closed for but one or two seconds. In a similar manner effects called kathodic-opening-contractions and kathodic-closure-contractions have been noticed.

Therapeutic treatment by means of a steady galvanic current is called galvanization. Galvanization may be either local, general, or central.

In general galvanization, as the term would indicate, the current is applied therapeutically by means of electrodes of sufficient size to direct the current practically through the entire body.

In local galvanization, the therapeutic current is applied only to particular organs or parts of the body, in distinction to general galvanization.

In central galvanization, which may be regarded as a variety of general galvanization, the kathode is placed on the epigastrium and the anode is moved over the different parts of the body.

Methods of galvanization may also be divided into labile and stabile galvanization.

In labile galvanization, the galvanic current is supplied by keeping one electrode firmly in contact with one part of the body, while the other electrode is moved over the parts of the body to be treated.

In stabile galvanization, the current is caused to pass continuously and steadily through the portions of the body that are undergoing galvanization, and the current is applied to and removed from the body gradually in order to avoid the shocks at the beginning and end of the application.

The treatment of the body by means of the faradic current is called faradization. Faradization is either general or local.

In local faradization, the faradic current is applied in a manner similar to that of local galvanization.

Sometimes both the faradic and galvanic cur-

rents are applied simultaneously. This method is called galvano-faradization. It is claimed that the simultaneous excitation of a nerve by both a voltaic and a faradic current, by utilizing the well-known refreshing effects produced by the galvanic current, has the effect of decreasing the fatigue which would otherwise follow energetic faradization. This treatment has been applied especially in the case of chrònic rheumatic swellings of the joints.

Faradic currents are sometimes employed in a somewhat modified form in what are called swelling faradic currents. In this form of faradization the current strength gradually increases, is maintained at its maximum for a few minutes, and then gradually decreases to zero, these variations being repeated during the application.

Faradic currents are generally obtained by means of variously constructed induction coils, called medical induction coils.

One form of such medical induction coil is shown in Fig. 87.

The treatment of the body by means of Franklinic electricity is called Franklinism. There are various methods of employing the franklinic current, namely:

(1.) The method of static insulation or charge, in which the patient is placed on an insulated stool and

his body connected with one pole of an electrostatic influence machine by means of a metallic conductor, and the other pole of the machine is grounded. While in this position the body is alternately charged and discharged every few moments. A modification of the above method consists in subjecting the body to shocks from two small Leyden jars connected to the opposite poles of the machine.

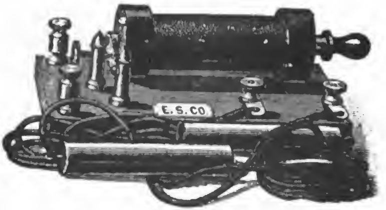

FIG. 87.—MEDICAL INDUCTION COIL.

(2.) The method of static breeze, in which one pole of the machine is connected to the body of the patient and the other is furnished with a series of points formed into a brush placed or moved over the parts of the body to be treated.

The electric current is frequently applied therapeutically to all parts of the body by means of various electro-therapeutic baths, in which either voltaic or faradic currents are employed. These baths are of a great variety of forms.

In the uni-polar electro-therapeutic bath the water forms one of the electrodes, the other being formed by a metallic rod fixed at a convenient height above the tub, formed of non-conducting material. The end of the electrode connected with the water terminates in metal plates suitably located below the water line in the tub. The current is applied by the patient making and breaking contact at the vertical metal rod with his hands.

In the bi-polar electro-therapeutic bath, the points at which the current enters and leaves the body are both placed underneath the water, so that the discharge is passed directly over those portions of the surface of the body of the patient that is placed between the electrodes.

In the multipolar electro-therapeutic bath more than two electrodes are employed. It is by no means clear that this bath possesses any advantages over the bi-polar bath.

When an electric current is sent through a porous wall or partition separating two liquids of different densities, a flow or streaming of one of the liquids through the pores of the wall is produced in the direction in which the current is passing. This phenomenon has received the name of cataphoresis, or electric osmose.

Cataphoresis has been successfully applied in electro-therapeutics for the purpose of introducing drugs or medicaments into the body for curative purposes ; such an application is called cataphoretic medication.

Since, when an electric current is sent through the body, it must, necessarily, pass through the walls of various parts separating fluids of different density or composition, such flow must be attended by the partial depletion of some organs and the engorgement of others. It is probable that much of the electro-therapeutic action of a current depends on this action.

A very important application of electricity to electro-therapeutics is to be found in the cautery-knife electrode, which consists essentially of a metallic knife-shaped electrode, that is rendered incandescent by the passage of an electric current through it. Various shapes are given to this instrument. In order to prevent the heat from appearing at any other part than in the cautery proper, the conducting wires that lead the current to and from the cautery are formed of some good conductor of electricity, such as copper.

In most cases the heated wire can be drawn in or shortened by means of a ratchet wheel, so as to en-

able the incandescent wire to cut or burn its way through the tissues that are to be removed.

In many cases use is made in medicine of the electric light for purposes of exploration. Such apparatus consists generally of small incandescent lamps that are placed at the ends of electrodes, suitably shaped for introduction into various parts of the body.

Quite a variety of these lamps have been devised, such, for example, as those for the illumination of the larynx, the stomach, bladder, the vagina, etc.

In the electric probe, a metallic conductor is inserted in the body of a patient in order to ascertain the exact position of a bullet or other foreign metallic substance.

The conductors are placed parallel, and are separated at the extremity of the probe by any suitable material. On contact with the metallic substance, an electric bell is rung by the closing of the circuit, or the same thing is more readily effected by the deflection of the needle of a galvanometer, or by a telephone placed in the circuit. Sometimes Hughes' induction balance is used for the same purpose.

According to some authorities, electric currents and charges are present in all living nerves and muscles. The amount of these currents, during

the normal condition of the body, is fixed and definite; in diseased conditions, however, the electricity varies, sometimes being in excess and sometimes being in deficit.

According to other authorities, electrical currents or charges are entirely absent in passive normal nerve or muscle tissue, and are only present during abnormal conditions of the same. Although many authorities lean to this belief, yet, considering the human body in the light of a complicated machine, in which chemical actions are constantly occurring, and in which liquids are being forced through various diaphragms, it is difficult to consider the normal living human body as entirely devoid of electric currents or charges.

It would not seem at all improbable that it is in this direction that advances in the near future will be made in the domain of electro-therapeutics. It is probable that, heretofore, electro-therapeutists have erred in regarding the human body only as a something through which electric currents are to be sent solely for the purpose of producing changes in the organs through which they pass.

If it be true that healthy normal muscle and nerve tissues, in the living animal, possess definite charges and currents, it would seem probable that the direc-

tion in which the electro-therapeutists can accomplish the greatest good is in applying currents or charges for the purpose of either directly restoring the normal charges and currents, by electricity added from without, or for the purpose of stimulating nervous and muscular tissue, and so altering their nutrition or assimilation as to bring about or restore such electrical conditions from within.

The two opposing views that are thus held respecting the natural presence of charges or currents in the human body are called respectively the molecular theory of muscle or nerve current, and the alteration theory of muscle or nerve current.

The molecular theory of muscle or nerve current, proposed by Du Bois Raymond, regards each muscle or nerve fibre as composed of a number of electromotive molecules arranged in series and surrounded by a neutral conducting fluid.

The alteration theory of muscle and nerve current, proposed by L. Hermann, regards the currents of nerves or muscular fibres as being produced only as a result of alteration from a healthy condition. Hermann's theory may be briefly summarized as follows:

(1.) Protoplasm undergoing partial death at any

part, either by dying or by metamorphosis, becomes negative to the injured part.

(2.) Protoplasm when excited at any part becomes negative to the unexcited part.

(3.) Protoplasm heated at any part becomes positive to the unheated part, and on cooling negative to such part.

(4.) Protoplasm is strongly polarizable on its surface, the polarization constantly diminishing with excitement and while dying.

According to the alteration theory, passive, uninjured and absolutely fresh tissues are entirely devoid of electrical currents. This theory would seem improbable, since, during the life of an animal, passive and absolutely uninjured fresh tissues would appear to be impossible.

Probably one of the most promising applications of electricity in electro-therapeutics is in the direction of electric diagnosis and prognosis.

In electric prognosis electricity is employed to ascertain the healthy or diseased conditions of certain organs or tissues.

In certain diseased conditions of the body profound changes occur in the irritability or excitability of the nerves or muscles by electricity.

In some cases there exists a complete inability of

the tissues to transmit electric impulses; in other cases the electric irritability is either increased or decreased.

Besides the changes in muscular tissues, as indicated by their response to electric excitement, changes are noticed in the manner in which they contract. These changes apparently indicate that a degeneration is taking place in their structure. Electric stimulation, instead of producing a well defined, quick jerk, produces a long-drawn, lazy movement. Those reactions, which are generally known in electro-therapeutics under the term reaction of degeneration, afford an opportunity to an intelligent practitioner of making an electric prognosis as to the probable termination of the disease.

The following facts concerning the reaction of degeneration are condemned from Landois and Sterling, viz.:

(1.) Typical reaction of degeneration occurs when the reaction of the nerve and muscle to electric stimulation is altered both qualitatively and quantitatively.

(2.) The faradic current decreases or abolishes the excitability of the muscles.

(3.) The galvanic current increases such excitability from the third to the fifty-eighth day; it

again diminishes with variations from the seventy-second to the eightieth day.

(4.) The anode closing contraction is stronger than the cathode closing contraction.

(5.) The decrease in the excitability of the nerves is similar for the galvanic and the faradic currents.

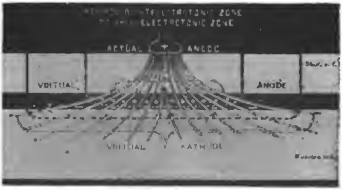

FIG. 88.—KATHODIC AND ANODIC REACTIONS.

Fig. 88 represents what De Watteville assumes is taking place in the human body at the points of entrance and exit of a current in a nerve submitted to the action of the anode of an electric source. According to him, two zones are formed, an anodic and a kathodic zone; the virtual anode is formed by the portion of the skin lying nearer the nerve, and the virtual kathode by the adjoining muscles. There are thus formed two zones

of influence, one immediately around the anode, called the polar or anodic electrotonic zone, and one surrounding this and including the virtual kathode, and called the peripolar, or kathelectrotonic zone.

EXTRACTS FROM STANDARD WORKS.

Liebig and Rohé, in their "Practical Electricity in Medicine and Surgery,"* speaking of electric diagnosis, on page 187, say:

"Both the faradic and galvanic currents are used for diagnostic purposes in pathological conditions of nerves and muscles.

"When the faradic current is employed it is of little consequence which pole is used, as the reaction of the nerve and muscle is the same in quality for both poles. The secondary spiral acts, however, with greater intensity, and is for this reason usually employed.

"On the other hand, when the galvanic or constant current is used, the selecting of the pole to which the testing electrode is attached is of the greatest importance. This will be readily appreciated when it is borne in mind how differently the two poles act upon nerve and muscle, and upon the organs of special sense, in their normal condition.

"The diagnosis of morbid conditions of nerves and muscles by means of the electric current demands certain special qualities in the physician that will have been appreciated, perhaps, by those who have read the preceding sections of this work. The electro-diagnostician must have

* "Practical Electricity in Medicine and Surgery," by G. A. Liebig, Jr., Ph. D., and George H. Rohé, M. D. Philadelphia: F. A. Davis. 1890. 383 pages, illustrated. Price, $2.

a good practical knowledge of the apparatus employed, and he must be familiar with the location of the various motor points of muscles, and of the effects produced when these are stimulated in their normal condition.

"In order to permit the comparison of different observations, the same apparatus—batteries, electrodes, galvanometers, rheostats, etc.—should always be used. Care must be taken that the connections in the circuit are tight and without insulation, and, unless previously determined, the anode and kathode should be found by experiment and appropriately marked.

"The electrodes most suitable for testing are the so-called 'normal' electrode of Erb, and the 'unit' electrode of Stintzing. The former has an area of ten square centimetres and the latter three square centimetres. With the latter finer work in isolating nerves lying close together can be done, but its use requires an exactness of anatomical knowledge which is not very common. Hence, for practical purposes the normal electrode of Erb will give greater satisfaction.

"The testing electrode should have a key for closing and opening the circuit conveniently in the handle. More complicated electrodes, such as contain commutator and rheostat in the handle, are not desirable, since they are liable to get out of order, and are either cumbersome or untrustworthy.

XIV.—PRIMER OF PRIMERS.

On account of the great velocity with which it is propagated electricity is especially adapted for the rapid transmission of intelligence between different points.

A system for the electric transmission of intelligence consists essentially of the following parts, namely :

(1.) A conductor, or its equivalent, connecting the different points.

(2.) Transmitting instruments designed for sending varying electric impulses over the conductor.

(3.) Receiving instruments for producing signals by means of the electric impulses sent over the conductor.

(4.) An electric source placed in the circuit of the conductor and designed to furnish the electricity required.

In nearly all systems of communication, both receiving and transmitting instruments are placed at each station.

In lines of great length, the electric impulses received at the distant end are strengthened by means

of local batteries, automatically connected to the line by means of instruments called relays.

The line wire or conductor can be arranged either in the form of a metallic circuit or as a ground-return circuit.

In establishing a ground circuit, care should be taken to see that the ends of the line are in good electrical connection with the earth. This can be insured either by connecting the ends with metallic plates that are sunk into the ground sufficiently far to reach permanently moist strata, or by connecting such ends to the gas or water pipes.

Rays of light are sometimes employed in establishing circuits for the electric transmission of intelligence.

For aërial lines, bare wires or conductors may be employed. In this case the wires are supported on variously shaped insulators placed on poles.

Where the lines are to pass under ground or below a water surface, some form of insulating material is placed over the wire as a coating or covering. This covering is rendered impervious to water and is generally further protected by means of a metallic armor or sheathing. Such conductors are called cables.

The transmitting instruments for most systems of

telegraphic communication consist substantially of keys, the alternate to-and-fro motions of which open and close, or close and open, the circuit of the line wire or conductor.

In some cases, as in the articulating telephone, the transmitting instrument is operated by means of the sound waves produced by the speaker's voice.

The receiving instruments employed in various systems for the electric transmission of intelligence, though of a variety of forms, most generally consist of some form of electro-magnet, the to-and-fro movements of whose armature are utilized for the production of various signals.

In the Morse system of telegraphy the electric impulses are received as dots and dashes on a moving fillet of paper, or as a series of clicks that are received by the operator as audible signals.

In some systems of telegraphy the message is received by means of the movements of a magnetic needle, movements in one direction corresponding to the dots of the Morse alphabet and in the opposite direction to the dashes.

In the printing telegraph the message is received on a fillet of paper as a printed dispatch.

The impulses sent over the line may, however, actuate the armature of an electro-magnetic re-

ceiver, so as to cause it to ring bells, release drops, display signals, regulate clocks, or to perform a variety of similar acts.

The telephone is an apparatus by means of which both musical sounds and articulate speech can be transmitted from one end of a line wire or conductor to the other end where they are reproduced.

The instrument at the sending end is called the transmitter; the instrument at the receiving end is called the receiver.

The articulating telephone was invented by Reiss in 1861, and improved by Bell in 1876.

The three characteristics of musical sounds are tone or pitch, intensity or loudness, and quality or timbre.

Differences in tone or pitch are due to differences in the number of vibrations per second, or in the lengths of the waves produced; the shorter the waves, the greater the number of vibrations per second, and the shriller and more acute the tone or pitch.

Differences of intensity or loudness are due to differences in the amplitude of the sound waves, or to the difference in the amount of energy charged on the medium through which the sound waves are moving.

Differences in the quality or timbre of musical sounds are due to differences in the character and intensity of the additional tones called overtones.

Articulating telephones may be divided into two classes :

(1.) Those in which the energy of the sound waves is utilized for the production of electrical currents, which, when transmitted over the line wire or conductor produce at the other end of the line sounds of exactly the same character as those spoken at the transmitting end.

(2.) Those in which the energy of the sound waves is employed to produce, in the strength of the current furnished by a battery or other electric source, variations or modifications corresponding to differences in the sound waves, which currents, when transmitted over a line wire or conductor, reproduce in the receiving instrument the sounds which caused them.

At each end of a telephone wire or conductor a transmitting and receiving instrument is employed in connection with a call bell connecting each subscriber with a central station at which a suitable switchboard is provided for placing any subscriber in circuit with any other subscriber.

In the automatic telephone switch a conductor is

arranged whereby the mere removal of the telephone from a hook provided for its support, automatically closes the circuit of a local battery through the circuit of the transmitter, disconnects the telephone from the circuit of the call-bell, and connects it with the circuit of the transmitter.

The microphone consists essentially of a variable contact-transmitter that is operated by means of sound waves, and depends for its operation on variations in the current due to variations in the resistance produced by sound waves acting on a loose contact.

A telephonic relay consists of a device whereby the rapidly varying and undulatory currents sent through a telephone circuit are automatically reproduced and transmitted through another circuit.

In the Edison loud-speaking telephone the receiving instrument is operated on the principle of the electro-motograph, in which the friction of a platinum point, against a rotating cylinder of moistened chalk, is reduced by the passage through it of an electric current.

In the electro-capillary telephone the movements of the transmitting diaphragm produce electric currents as the result of variations in the extent of the contact surfaces of liquids in capillary tubes. These

currents being sent through the line wire or conductor reproduce, in similarly constructed receiving instruments, the motions that produced them.

In the photophone the telephonic transmission of speech is carried on along a ray of light instead of along a conducting wire.

The phonograph is a device whereby articulate speech, or sounds of any character, can be reproduced at an indefinite time after their occurrence, by means of characteristic indentations produced on a sheet of tinfoil or hardened wax, by the to-and-fro motions of a point or stylus on a diaphragm against which the speaker's voice is directed.

A system of telegraphic or telephonic communication includes a line wire or conductor connecting two stations between which intelligence is to be transmitted. Various transmitting and receiving instruments are generally placed both at the ends of the wire and at intermediate stations as well.

A telegraphic circuit is either metallic or an earth circuit.

The receiving instruments employed in telegraphy are generally electro-magnets the armatures of which are either non-polarized or polarized.

A receiving instrument with a non-polarized armature is moved in one direction by the action of the

magnetism produced when the current circulates through the magnetizing coil, and is moved in the opposite direction by the motion of a spring or weight.

A receiving instrument with a polarized armature will move in one direction when the magnetizing current is sent in one direction through the coils of the electro-magnet, and in the opposite direction when the current is sent in the opposite direction.

Receiving instruments with polarized armatures follow changes in the strength of the current only.

Receiving instruments with non-polarized armatures follow changes in the direction of the current only.

In telegraphic systems the line wire or conductor may be maintained—

(1.) On a closed circuit, as is generally employed in America in the Morse system ; or,

(2.) On an open circuit, as in all needle systems, and, in England, in the Morse system.

In the Morse system of telegraphy a series of makes-and-breaks in the current are caused to follow one another at certain arbitrary intervals, which represent the letters of the alphabet.

The circuit is opened and closed at proper intervals by means of a telegraphic key.

A Morse recorder is an instrument by means of which the to-and-fro movements of the armature of the receiving instrument, or the receiving relay, as it is called, are permanently recorded on a moving fillet of paper by means of a stylus or pen connected with the armature of an electro-magnet.

In the ink-writing recorder or register, a record is made in ink on a moving fillet of paper.

In the Bain recorder, the dots and dashes of the Morse alphabet are marked on a moving fillet of paper soaked in some chemical substance, so that, on the passage of the current, marks are produced by the decomposition of such substance by the current.

In the Morse sounder, the message is read by means of the sounds or clicks produced by the to-and-fro movements of the armature of the receiving electro-magnet, the dots and dashes being reproduced by audible signals that are readily distinguished by the operator by means of the difference in the sounds produced by the up and down strokes of the lever, as well as by the varying intervals of time between the successive sounds.

A telegraphic relay is a device whereby very feeble electric impulses, received at the distant end of a long line, operate a sensitive apparatus and open or close

the circuit of a more powerful local battery and thereby operate a sounder or recording instrument, which requires a more powerful current than that sent over the long line.

In needle telegraphy the messages are received by means of the movements of a vertical needle to the right or left of its position when at rest. Motions to the right correspond to the dashes, and motions to the left, to the dots of the Morse alphabet.

In step-by-step or dial telegraphy the signals are received by the movements of a needle over a dial on which the letters of the alphabet and numerals are marked. The movements of the needle are made, step-by-step, by the to-and-fro motions of the armature imparting their motion to a suitably shaped toothed wheel.

In the printing telegraph the message is received in ordinary printing-type characters on a moving fillet of paper. A type wheel, on the circumference of which the type are placed, is turned in a step-by-step movement, by means of suitable impulses sent over the line, and, when the character it is required to transmit comes opposite the fillet of paper, an electro-magnet presses such character against the fillet of paper and thus imprints it thereon.

In fac-simile telegraphy, a copy of a chart, dia-

gram, picture, or signature, is telegraphically transmitted from one station and reproduced at a distant station.

In induction telegraphy means are devised whereby communication is established between a moving train of cars and a fixed station along a railroad by means of impulses transmitted by induction between the moving train and a wire extending parallel to the track. Induction telegraphy embraces two systems; namely,

(1.) The electro-static induction system.

(2.) The current induction system.

Multiple telegraphy includes devices for increasing the capacity of a single telegraphic line so as to permit the simultaneous transmission over it of more than a single message.

The most important systems of multiple telegraphy are :

(1.) Duplex telegraphy.

(2.) Quadruplex telegraphy.

(3.) Synchronous multiplex telegraphy.

(4.) Harmonic telegraphy.

(5.) Phonoplex telegraphy.

Duplex telegraphy consists of means by which two messages can be simultaneously sent over the same line wire or conductor. It embraces diplex, in

which two messages are sent in the same direction, and contraplex, in which they are sent in opposite directions.

There are two varieties of duplex telegraphy ; namely,

(1.) The bridge method.

(2.) The differential method.

In any system of duplex telegraphy two conditions must be obtained; namely,

(1.) The receiving instrument at one end of the line must not respond to its own key.

(2.) Currents coming from either end of the line must be provided with a free or uninterrupted path to the earth or ground.

In the bridge method of duplex telegraphy the receiving relay at each end of the line is placed in the cross wire of a Wheatstone bridge.

In the differential method of duplex telegraphy the receiving relays at each end of the line are wound differentially.

Quadruplex telegraphy consists in means whereby four messages can be simultaneously transmitted over a single line wire or conductor; two in one direction, and two in the opposite direction.

Quadruplex telegraphy consists briefly in means whereby duplex telegraphy is duplexed.

There are two distinct methods of quadruplex telegraphy; namely, the bridge method and the differential method.

Synchronous multiplex telegraphy consists in means whereby a great number of messages can be simultaneously sent over a line wire or conductor, either all in one direction, or a part in one direction and the remainder in the opposite direction.

In synchronous multiplex telegraphy means are devised whereby the line wire or conductor is in effect taken from one operator and transferred to another so rapidly that he cannot tell but that he has the line alone. By these means the line is practically ready for the use of each operator as if he alone had control of it.

In harmonic multiple telegraphy means are provided for the simultaneous transmission of a number of separate and distinct musical sounds through a single wire, which are utilized for the transmission of an equal number of telegraphic despatches.

In phonoplex telegraphy pulsatory currents actuate a modified telephonic receiver, which thus permits the simultaneous transmission of several separate messages over a single wire without interference.

When the line wire or conductor is buried in the

ground or placed under a water surface it must be insulated at all parts of its circuit. Such a conductor is called a cable.

The means employed for sending telegraphic dispatches over cables are somewhat different from those employed in ordinary cases.

There are three parts to every cable, namely,

(1.) The conducting wire or core.

(2.) The insulating material surrounding the core.

(3.) The protecting covering called the armature or sheathing.

Cables may be divided into various classes, according to the manner in which their wires are disposed. Where more than a single wire or conductor is employed it is called a bunched cable. In bunched cables the separate wires may be disposed or laid-up, straight-away or twisted.

Before a telegraphic wire can transmit a signal to its farthest end its difference of potential must be raised to an amount depending on the character of the instrument and the nature of the circuit; that is, the line wire must receive a certain charge before the current sent into it can produce a signal at the other end.

The amount of this charge will vary with the length of the wire, the extent of its surface and the

neighborhood of the earth or other wires. This discharge is lost as a current for signaling, and the greater its value—that is, the greater the capacity of the line wire—the greater will be the retardation in the signaling.

By retardation in signaling is meant the decrease in the speed of transmission caused either by mutual induction between it and neighboring conductors, by condenser action, and by magnetic inertia or lag, or by the time required to magnetize and demagnetize the cores of the electro-receptive devices.

The retardation is marked in electric cables on account of the induction produced in their metallic armor or sheathing, and also because the core of the cable and the metallic sheathing act as a condenser.

In order to diminish the retardation in the case of cables the impulses employed in cable telegraphy are exceedingly feeble, and very delicate receiving instruments are, consequently, required to be employed.

The receiving instrument employed in cable telegraphy is sometimes a Thomson reflecting galvanometer, or some modification thereof, in which case no permanent record is left of the message. Generally, however, a siphon recorder is employed which leaves a permanent ink-tracing on a paper fillet.

An electric annunciator is a device for automat-

ically indicating the places where electric contacts have been closed by the falling of a drop or the movement of a needle, to which attention is called by the ringing of a bell.

The bells employed in connection with annunciators are of the automatic type, in which the bell rings as long as a current is passing through it; that is, as long as the contact remains closed, as by the keeping of a finger on a push button.

A push button is a device whereby the pressure of a button closes an electric contact against the action of a spring. When the finger is removed from the button the spring automatically opens the contact.

Electric annunciators may be divided into a variety of forms according to the purposes for which they are designed, such, for example, as the hotel, house, burglar and elevator annunciators, and fire-alarms and temperature-alarms.

Annunciators are generally operated by electromagnetic attractions and repulsions. Their automatic indications are obtained either by the falling of a drop or by the movement of a needle over a dial.

In a system of burglar alarms, devices are employed whereby the opening of a door, closet, window or safe, or the passage of a person through a

room or hallway, is automatically indicated on an annunciator. At the same time an alarm bell is automatically thrown into the circuit and continues to ring either while such contact remains closed, or until stopped by being thrown out of contact with the bell.

A thermostat is a device by means of which an electric circuit is automatically closed by the expansion of a rod, or liquid column, on a certain increase of temperature, and remains closed as long as such increase of temperature is maintained. On cooling, the contraction of the rod or liquid column automatically opens the circuit.

Thermostats are employed to notify an attendant when the temperature of a hot-house, incubator, tank or building, generally, has reached a certain predetermined point.

A call-box is a device whereby the mere pulling of a lever sends a call to a central office for some particular service, such, for example, as a messenger boy, the police, fire department, or some special service that is agreed upon.

The call is sent by means of a wheel set in motion by the pulling of a lever. On its rotation the wheel makes and breaks the circuit in a definite succession representing a certain call.

Liquid-level alarms are devices whereby any change in a water level beyond a certain predetermined point automatically announces the fact to an attendant by the ringing of a bell.

In the telemanometer means are devised whereby the pressure of a steam or water gauge, or the position of a mercury column in a pressure gauge, thermometer or barometer, is automatically indicated by the movements of a needle over a dial.

Time telegraphy embraces any system of telegraphic communication by means of which time is telegraphed from a standard or master clock over a line wire to a series of secondary electric clocks placed therein and moved, operated or regulated by the electric impulses thus telegraphed.

A system of time telegraphy embraces the following parts.

(1.) A master or standard clock, the movements of whose pendulum automatically transmit timed impulses over a conductor to secondary clocks placed in the circuit.

(2.) A number of secondary clocks placed in the circuit of the master clock and either operated or regulated by timed impulses from the master clock.

Secondary clocks consist generally of ordinary clock dials the hands of which are moved by the

step-by-step movement of the armatures of electro-magnets operated by means of impulses from the secondary clocks.

Electric clocks may be divided into three classes—

(1.) Those operated entirely or partly by the electric current.

(2.) Those which are only controlled or regulated by the electric current.

(3.) Those which are merely wound by the electric current.

In self-winding clocks an electric motor, operated by some open-circuited voltaic cell, is employed at regular intervals to automatically wind the clock.

In some systems of time telegraphy the exact time is indicated to an entire neighborhood by the falling of a time-ball, or by the firing of a time-gun.

Electric clocks are sometimes connected to the circuit of an annunciator, by means of which the movements of their hands or works, at certain predetermined times, close contacts, ring bells, release drops or perform similar work.

In watchmen's registers a record is kept of the exact time of the visit of a watchman to each of a number of stations in the district or building he is watching.

The electro-chronograph is a device whereby

exceedingly minute intervals of time are correctly measured and registered.

The time is determined by the to-and-fro motions of the pendulum of a clock or tuning fork.

The decomposition of a chemical substance by the passage through it of an electric current is termed electrolysis.

The power of electricity to cause the chemical decomposition of water was first positively pointed out by Nicholson on May 2d, 1800. On October 5, 1807, Sir Humphry Davy decomposed potash into potassium and oxygen.

In electrolysis the molecules of the electrolyte are decomposed or separated into atoms or groups of atoms or radicals called ions. These ions are respectively electro-negative and electro-positive.

The electro-negative ions, or, as they are generally called, the anions, are those which appear at the anode or terminal connected with the electro-positive terminal of the source.

The electro-positive ions, or, as they are generally called, kathions, appear at the kathode or at the electro-negative terminal.

The terms anions and kathions therefore apply not to the polarity of the ions themselves, but to the polarity of the electrodes at which they appear.

The electro-positive radicals are called kathions because they appear at the electro-negative electrode or kathode. Electro-negative radicals are called anions because they appear at the electro-positive electrode or anode.

The vessel containing the electrolyte in which electrolysis is taking place is called the electrolytic cell.

When an electrolytic cell is arranged so as to measure the strength of the current that passes by the amount of chemical decomposition effected it is called a voltameter.

The amount of chemical decomposition effected by the current is proportional to the amount of electricity that passes through the circuit; that is, it is proportional to the number of coulombs that pass.

Faraday's laws of electrolysis may be expressed as follows, namely:

(1.) The amount of the electrolyte decomposed is directly proportional to the quantity of electricity that passes through it.

(2.) If the same current passes through different electrolytes the quantity of each ion evolved per unit of time is proportional to its chemical equivalent.

The chemical equivalent of a substance is the quotient obtained by dividing the atomic weight of

the substance by its atomicity. Or, the chemical equivalent is the ratio between the quantity of an element and the quantity of hydrogen it is capable of replacing in combination.

The electro-chemical equivalent of a substance is the weight of the substance in grammes that is liberated during electrolysis by the passage of one coulomb of electricity. The electro-chemical equivalent of any substance is found by multiplying the electro-chemical equivalent of hydrogen by the chemical equivalent of the element.

The laws of electro-chemical equivalance may be expressed as follows: The chemical action produced by an electric current, when passed through different substances, is proportional to the chemical equivalent of each substance, that is, to its atomic weight divided by its valency.

The passage of the same quantity of electricity through different electrolytes liberates the same number of atoms of a monad element, no matter what their nature may be. It liberates one-half as many diads, and one-third as many triad atoms as it does monads.

In the opinion of some, the cause of chemical attraction or chemical affinity is to be traced directly to electric charges possessed by the atoms.

These charges are believed to be naturally possessed by the atoms and never to be lost by them.

When electrolysis occurs an opposing electromotive force is set up called the counter-electromotive force of polarization. To effect electrolysis, therefore, the electromotive force producing the decomposition must be at least as great as that of the opposing electromotive force.

Since in the case of electrolysis effected by means of an anode formed of the same metal as that deposited at the kathode there is no counter-electromotive force produced, an exceedingly feeble current is capable of causing decompostion ; as, for example, of depositing copper from a solution of copper sulphate when a copper plate forms the anode of the bath.

No actual transfer of the ions is believed to take place during electrolysis between the electrodes. Grotthüss explains the action which takes place by a polarization of the molecules of the electrolyte attended by a rotation of the same upon their axes.

Under certain circumstances electrolysis can be effected by means of alternating currents.

Electro-metallurgy is that branch of electricity which treats of electro-metallurgical processes effected by the aid of electricity.

It includes the following branches:

(1.) Electro-plating.

(2.) Electrotyping.

(3.) The electrical reduction of metals.

Electro-plating is that branch of electro-metallurgy which treats of the various processes for covering any electrically conducting surface with a metal by means of electricity.

The metals and their alloys can be deposited from their solutions by the process of electro-plating as thin, coherent, adherent, metallic coatings.

Before placing the article that is to be plated in the plating bath it must be subjected to various processes whereby chemically clean surfaces are obtained. This cleaning is effected by rubbing with various scratch-brushes and by dipping in baths of various liquids.

When silver is to be deposited the surfaces that are to receive the coatings are preferably subjected to a process called the quickening process, which consists essentially in covering the surfaces of the articles with a thin layer of mercury.

The stopping-off process is employed in electro-plating when it is desired to have only certain portions of the article plated. This is effected by

means of certain non-conducting varnishes called stopping-off varnishes.

When an article is to receive a coating by electroplating, after it is thoroughly cleansed it is connected to the negative electrode of a battery and placed in a plating bath containing a solution of the metal with which it is desired to coat it. A plate of the same metal, connected to the opposite terminal of the battery, is placed in the bath opposite the article to be coated. Under these circumstances the metal is deposited on the object that is to be plated by the decomposition of the liquid in the bath. The strength of this liquid is maintained constant by fresh metallic salts being formed by the gradual solution of the plate of metal connected with the anode.

In sectional plating a greater thickness of the coating is obtained at certain parts of the article than at others.

A plating balance is a device for automatically disconnecting the plating battery from the article that is to be plated as soon as a certain increase in weight has been obtained.

A stripping bath is employed whenever the metallic coating or plating of an article is to be removed, either for the purpose of economy or in order to fit the article for replating.

The deposits obtained in electro-plating are of two kinds; namely,

(1.) Reguline or flexible, adherent and strongly coherent deposits.

(2.) Crystalline or non-adherent and non-coherent deposits.

Electrotyping is that branch of electro-metallurgy by means of which cuts, reproductions, or duplicates of various objects are obtained in metal.

Since the process of electrotyping produces the same results which were previously obtained by pouring fused metals in molds it is sometimes called the cold casting of metals. It is also sometimes called the galvano-plastic process.

Electrotypes are fac-simile reproductions, by the process of electrotyping, of copper, wood or steel engravings.

The electric furnace is a device whereby heat, electrically generated, is employed either for the purpose of effecting difficult fusions, for the extraction of metals from their ores, or for any other electro-metallurgical process.

Various forms of electric furnaces have been devised in which either heat alone, or heat in the presence of carbon, or heat together with electrolysis is employed.

Electricity has been applied to the refining of metals, and for the direct production of phosphorus.

When it is desired to protect an exposed metal from oxidation, the device is sometimes adopted of placing somewhere in connection with it a piece of metal that is electro-positive to it. Under these circumstances the positive metal alone is attacked and the other metal protected.

A storage cell or battery is a device whereby the passage of an electric current through a battery or cell produces an electrolytic decomposition, which on the cessation of such current, permits the cell to act as a voltaic cell.

Storage batteries are sometimes called secondary batteries in order to distinguish them from voltaic or primary batteries.

The storage battery does not store electricity. It stores the energy of the electric current as potential energy in such a manner as to permit it to become kinetic as electric energy.

In the voltaic cell it is the chemical potential energy of the metal of the positive plate that maintains the flow of the current. In the storage battery it is generally the chemical potential energy of metallic lead deposited on one of the plates during electrolysis that maintains the flow of electric current.

Most storage batteries, in fact, form, in miniature, devices for the electrical reduction of a metal from an electrolyzable solution of the same, so that, when the charging current ceases to pass, the storage battery becomes, in point of fact, an ordinary voltaic battery.

The first storage cell was a gas battery produced by Ritter, of Germany.

When an electric current is sent through the electrolyte of an uncharged storage battery, the electrolyte is decomposed into its electro-positive and electro-negative ions or radicals. The former are deposited on the plate connected with the negative terminal of the storage cell, and the latter on the plate connected with the positive terminal.

According to the common usage of the terms, the positive plate of a storage battery is the plate connected to the positive terminal of the charging source. The negative plate is the plate connected to the negative terminal of the charging source.

In the ordinary storage battery employing lead plates in dilute sulphuric acid, the positive plate is the plate that is converted into or covered by lead peroxide by the charging current, and the negative plate the plate that is covered by or converted into spongy lead.

In the forming process the electric current is sent between two metallic plates through the electrolyte, first in one direction, and then, when a certain charge has been obtained, in the opposite direction, and the process repeated each time in opposite directions.

By these means the surface of the spongy lead plates and the amount of lead peroxide on the other plate are largely increased.

When a Planté storage battery is charged the negative plate is converted into spongy lead and the positive plate is covered with a layer of lead peroxide. Generally speaking, when the storage battery runs down both plates are covered with lead monoxide. When the battery is again charged the oxygen is removed from the negative plate leaving it covered with spongy lead and an atom of oxygen is carried to the positive plate, and converts the lead monoxide into lead peroxide.

In order to decrease the time required for forming Planté batteries, the lead plates are sometimes covered with lead peroxide or red lead.

Sulphating is a term applied to a difficulty sometimes experienced in the working of storage batteries from the abnormal formation of lead sulphate on the surfaces of the plate.

The best results are obtained from storage batteries when the rapidity of their discharge is not very great.

Electricity plays an important part in the art of war. It is employed on men-of-war for lighting and for maintaining powerful search lights; for the driving of electric motors; for hoisting, pumping and similar purposes; for the propelling of launches, torpedoes and boats; for charging storage batteries, and for numerous other purposes. It is employed on land not only in various systems of telephony and telegraphy, but also in apparatus called range-finders, and in various devices for igniting and exploding subterranean mines.

The search light consists essentially of a powerful voltaic arc so maintained at the focus of a parabolic reflector, as to throw an approximately parallel beam of light in any desired direction.

A well known form of search light is seen in the Mangin projector.

In Fiske's electric range-finder a device is provided for finding the exact distance of an enemy's ship or other object, so as to permit the gunner to make the proper allowance for range.

In Fiske's electric position-finder means are provided by which the exact position of an object can

be obtained so that a gunner can be telephoned or otherwise ordered to fire at objects he cannot see, and yet attain a fair degree of accuracy.

In the electric ammunition-hoist an electrically operated hoist is employed for the purpose of raising ammunition to the deck of a ship.

The electric log consists essentially of a wheel, placed in the water, which registers the number of its rotations by means of a step-by-step apparatus, and so gives the speed at which the vessel is moving.

Torpedoes consist essentially of water-tight compartments filled with some high explosive, which is either ignited by means of a fulminating cap or by means of a suitable electric fuse.

Torpedoes are either stationary or movable.

Stationary torpedoes are generally called submarine mines. They are exploded either by the shock of concussion on striking the enemy's vessel or by means of an electric spark.

Movable torpedoes are—

(1.) Drifting torpedoes.

(2.) Towing torpedoes.

(3.) Spar or outrigger torpedoes.

(4.) Automobile torpedoes.

The moving power is either carbonic acid gas, compressed air, or electricity.

Subterranean mines or stationary torpedoes consist of water tight cases containing explosives, which are anchored in suitable localities for the protection of a harbor.

Devices employed for igniting torpedoes or mines may be divided into two classes; namely,

(1.) High tension fuses, which are ignited by the direct action of an electric spark.

(2.) Low tension fuses, which are ignited by the incandescing of a wire when traversed by an electric current.

In the process of electric welding the metals that are to be forged are heated to electric incandescence by currents obtained from either suitable dynamos or transformers.

To successfully obtain a good welded joint it is necessary to heat the surfaces uniformly throughout, to protect them from dirt, and to be able to nicely regulate the amount of pressure between them.

In the Thomson process of electric welding the welding heat is obtained by electric incandescence.

The Thomson apparatus for welding is of two distinct classes ; namely,

(1.) The direct system of welding.

(2.) The indirect system of welding.

Electricity is extensively employed in mining for

driving various forms of electro-magnetic drills, as well as for tunneling and blasting purposes.

Electric drills may be divided into two classes; namely,

Rotary drills.

Percussion or reciprocating drills.

The various systems of electric gas-lighting can be divided into two classes; namely,

(1.) The separate system, or that in which a single gas jet is lighted at any one time.

(2.) The multiple system, or that in which a number of separate jets are simultaneously lighted.

In either system the issuing gas is ignited by an electric spark passing through it.

In the separate system this spark is obtained from a spark coil; in the multiple system from an induction coil, or some form of electrostatic induction machine.

In separate electric gas-lighting systems devices are employed by which the gas, after it has been turned on, is lighted by the pulling of a pendant, which causes the spark to pass through the issuing gas jet, or is both turned on and lighted, or extinguished, by the mere pulling of a pendant.

In some forms of gas-lighting burners the turning on and lighting the gas is effected by the pressing of

a push button, generally a white one, and the extinguishing of the gas by the pressing of another button, generally a black one.

In the multiple system of gas-lighting the gas is turned on by hand, generally by the turning of a single cock, and a series of sparks being then caused to simultaneously ignite all the gas jets by passing simultaneously through the escaping gas.

The Edison electric pen is a device employed for manifold copying, by means of which a sheet of paper is made into a stencil by the perforations of a needle maintained in a to-and-fro motion by a small electric motor.

The electric lock is a device whereby a door may be automatically unlocked by the pressing of a push button.

Electric heaters consist essentially of coils or circuits of some refractory material through which an electric current is passed sufficiently powerful to raise it to a high temperature.

Various other commercial applications have been made of electricity in electro-chemistry. The most important of these are electric tanning, electric bleaching and electric ageing of wines and the electric rectification of alcohol.

Hughes' induction balance is an apparatus whereby

the presence of a hidden conducting metal may be indicated by the use of induced electric currents.

An electric tasimeter is an apparatus for measuring minute differences of temperature or moisture by the resulting differences of pressure.

Electro-biology treats of the electric conditions of living animals and plants as well as the effects which electricity produces on them.

Electro-biology includes—

(1.) Electro-physiology.

(2) Electro-therapeutics.

Electro-therapeutics is that branch of electro-biology which treats of the applications of electricity to the curing of diseased conditions of the body.

Electricity is applied to the curing of diseases in a number of ways, the most important of which are—

(1.) By the use of variously shaped electrodes placed so as to cause a current to pass through the nerves or muscles so as to stimulate them to action or modify their nutrition.

(2.) Of various needle-shaped electrodes designed for introduction into the diseased growths so as to treat them electrolytically.

(3.) By using the heating power of the current as

in the galvanic cautery, which replaces the knife in the removal of diseased growths of the body.

(4.) In various applications of electro-diagnosis, electro-prognosis and electro-bisocopy.

(5.) By cataphoretic medication by means of which drugs or other medicaments are passed into the body, through its tissues, by means of an electric current.

Three distinct characters of current are employed in electro therapeutics ; namely,

(1.) The galvanic current, or that obtained from the voltaic cell.

(2.) The faradic current, or that obtained from induction coils.

(3.) The franklinic currents, or those obtained from frictional or electro-static induction machines.

When an electric current is sent through any particular part of the body the general character of the effects produced will vary according to the manner in which the current enters and leaves the body.

In such cases the effect will vary according to whether the anode or kathode of the battery is placed over the particular part of the body to be treated.

Generally the kathode produces the greatest effect though not always.

In any case the electrode which produces the principal effect is called the therapeutic electrode, and the other the indifferent electrode, because it appears simply to determine the points where the current shall leave the body.

Electrodes may be made in a variety of forms. They are named either from the organs they treat, or from their shapes, as aural, vaginal, urethral, brush, disc or point, clay or sponge electrodes. Non-polarizable electrodes are such as avoid the effects of polarization.

When an electric current is sent through a nerve the effect produced varies according to the character of the nerve and of the current.

When an electric current is passed through a nerve a condition of altered functional activity called electrotonus is produced.

The decreased activity which occurs in the neighborhood of the anode or positive electrode, is called the anelectrotonic state.

The increased functional activity, which occurs in the neighborhood of the kathode or negative electrode, is called the kathelectronic state.

The effect produced in a nerve, or in the muscles to which such nerve is connected, by the passage of an electric current varies according to

whether the galvanic or the faradic current is employed.

Therapeutic treatment by means of the galvanic current is called galvanization. Galvanization may be either local, general or central.

The treatment of the body by means of faradic currents is called faradization. Faradization is either general or local.

The treatment of the body by means of franklinic currents is called franklinism. Franklinism may be employed either by the method of static insulation or charge, or by the method of static breeze.

The electro-therapeutic bath is a device whereby electricity may be therapeutically applied to all parts of the body. Therapeutic baths are either unipolar, bipolar or multipolar.

The cautery-knife electrode is a device whereby a metallic knife-shaped electrode is rendered incandescent by the passage of an electric current through it, and is so arranged as to be readily employed to cut or burn its way through the tissues that are to be removed.

The electric light is frequently used for the purpose of medical exploration. For this purpose small incandescent lamps are placed at the ends of electrodes suitably shaped for introduction into various parts of the body.

A difference of opinion exists as to whether or not electric currents and charges are always present in living nerve and muscle tissues. According to some such currents or charges are entirely absent in passive normal tissues, and are present only during abnormal conditions of the same ; according to others they are always present in such tissues.

These theories are respectively embodied in the alteration theory of muscle and nerve currents of Hermann, and in the molecular theory of muscle and nerve currents of Du Bois Raymond.

Hermann's alteration theory of muscle and nerve current, regards the currents of nerves or muscular fibres as being produced only as a result of alteration from a healthy, normal condition.

Hermann's theory may be summarized as follows :

(1.) Protoplasm undergoing partial death at any part, either by dying or by metamorphosis, becomes negative to the injured part,

(2.) Protoplasm when excited at any part becomes negative to the unexcited part.

(3.) Protoplasm heated at any part becomes positive to the unheated part, and on cooling becomes negative to such part.

(4.) Protoplasm is strongly polarizable on its

surface, the polarization constantly diminishing with excitement and while dying.

In electro-prognosis electricity is employed to ascertain the healthy or diseased conditions of the tissues.

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